Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 JUNE 1953

31

Hydro-electric generating sets of outstanding performance

ENGLISH ELECTRIC

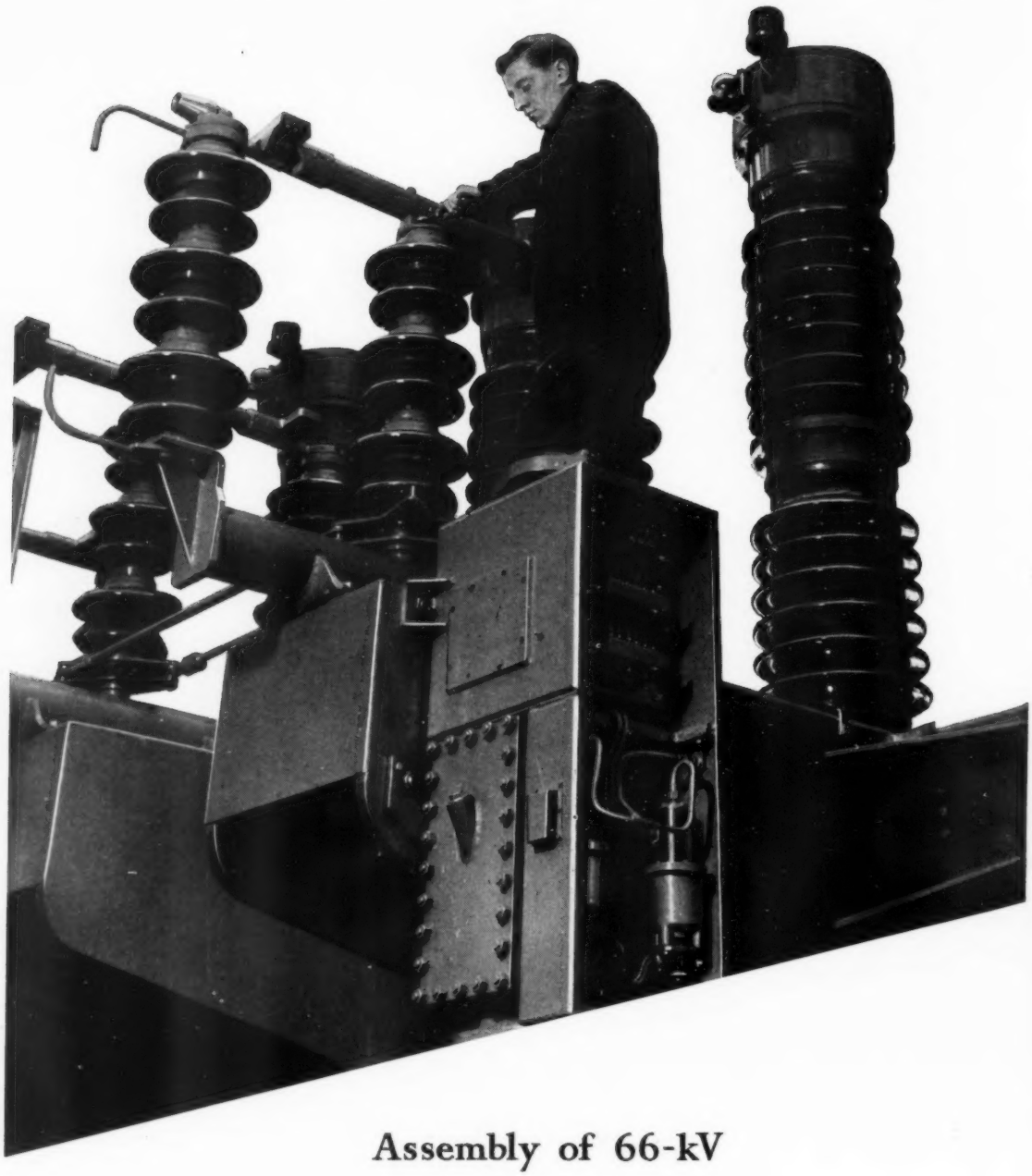
hydro-electric equipment

The twelve sets in the North British Aluminium Company's Lochaber Power Station, the earliest of which have operated for nearly thirty years, each comprise a 10,000 h.p. impulse water turbine driving two D.C. generators in tandem. Current output totals 240,000 amperes.

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Hydro-electric Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON



Assembly of 66-kV
small-oil-volume
circuit-breaker and
busbar-isolator

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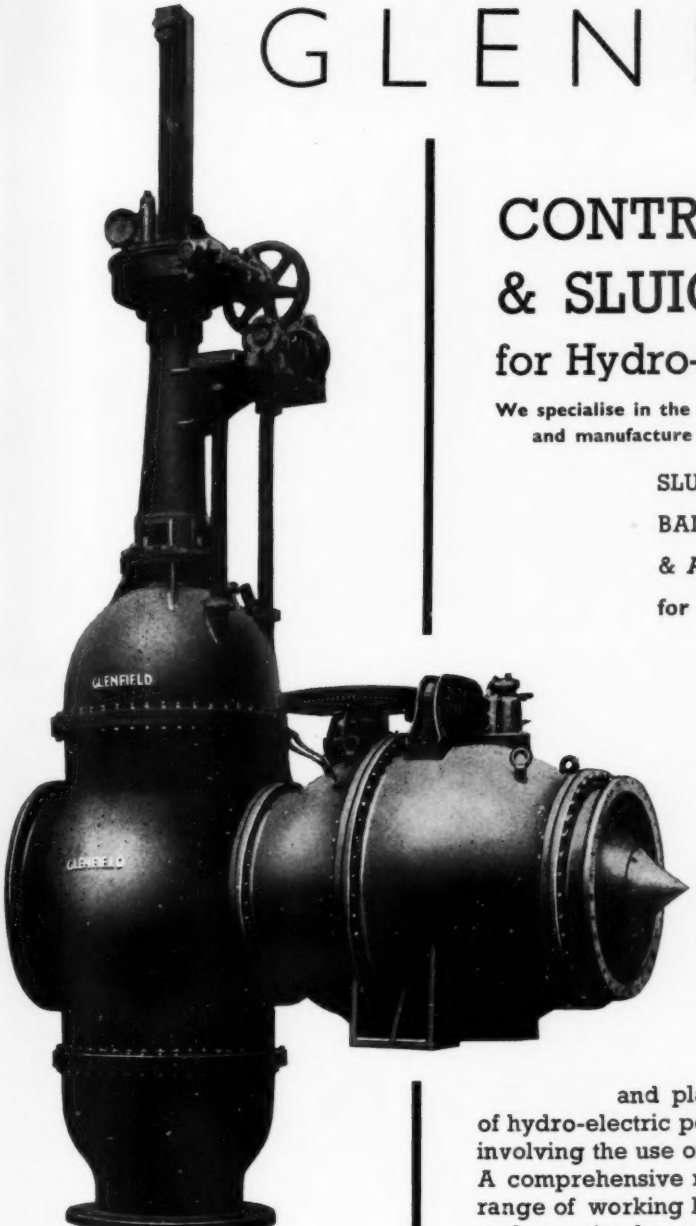
A. REYROLLE & CO. LTD., HEBBURN-CO. DURHAM

GLENFIELD



CONTROL VALVES & SLUICE GATES

for Hydro-Electric Power Plants

We specialise in the design and manufacture of

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BALANCED DISC VALVES
& ANTI-VACUUM VALVES
for pipelines

NEEDLE VALVES
& JET DISPERSERS
for positions of free discharge

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DRUM GATES
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for headworks

and place our experience at the disposal of hydro-electric power plant engineers in all matters involving the use of these equipments.
A comprehensive range of sizes and types for a wide range of working heads has already been developed, and any size for any working head is almost certainly possible of development.

The illustration shows a mechanically operated needle valve guarded by a motor operated follower ring type Sluice Valve for a free discharge application—a jet disperser is incorporated in the design of the Needle Valve for the safe dissipation of the issuing stream.

We solicit and welcome enquiries

Glenfield
GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

Head Office and Works: KILMARNOCK, SCOTLAND

The CEMENTATION COMPANY LIMITED

The Erne Hydro-Electric contract for the Electricity Supply Board of Eire, offers an interesting example of the best possible use of local materials in the construction of the works, resulting in a considerable saving of the total cost.

The rock from the excavation is hoisted in the skip hoist shown on the left of the picture, transported by conveyor to the crushing plant and manufactured and graded into five sizes of stone, including sand. This material is then conveyed to bins, having a total live storage of 5,000 tons.

The storage bins feed two 1 cu. yd. concrete mixers through automatic batching installations in tunnels beneath the bins. This allows simultaneous production of the various qualities of concrete, containing aggregate of different sizes required in work of this type, for an output of 3,000 cu. yd. of concrete per week.

The total labour force employed on the crushing and concrete mixing plant is 16 men. Need we therefore emphasise the resulting saving to clients in terms of accommodation and other expenses connected with the recruitment of labour, that are additional to the contract cost.

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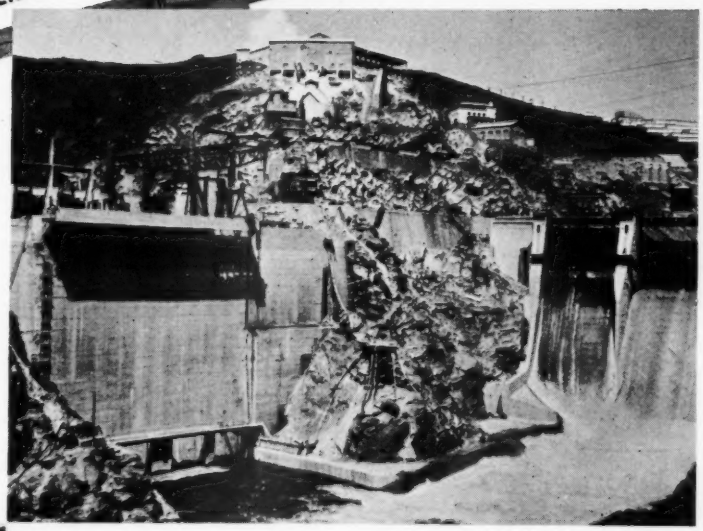
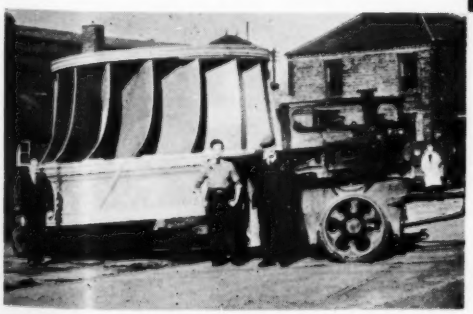
Boving

FRANCIS TURBINES FOR THE SALTO DE CASTRO PROJECT

At the Salto de Castro hydro-electric plant in Spain the first of two large Francis turbines was started up in August 1952. The turbines each develop 59,000 H.P. at 107 r.p.m. under a net head of 38 metres and were supplied by Boving & Co. Ltd., for Iberduero S.A.

Each runner is 4.4 metres (14 ft. 5 in.) diameter, weighs 47 tons and has 18 cast steel blades welded to cast steel hub and band with welded-on protection of stainless steel They are believed to be the largest fabricated runners yet built in Europe.





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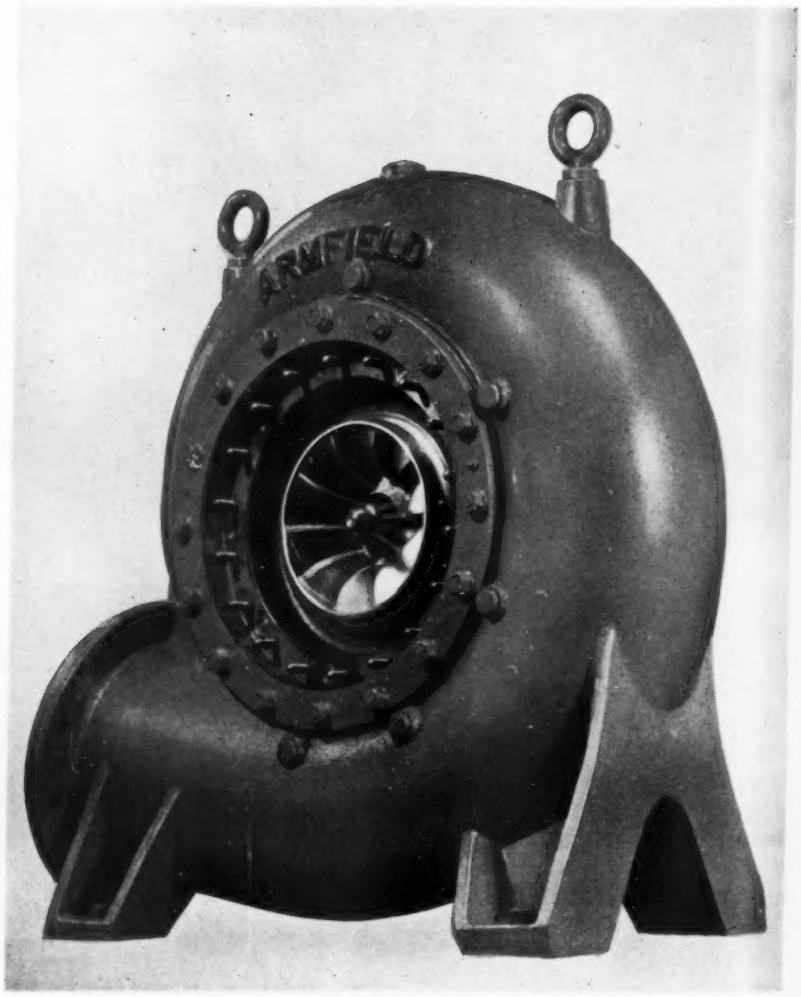
IN THE DESIGN AND MANUFACTURE OF

WATER TURBINES

UP TO 1,000 B.H.P.

The illustration is of a horizontal shaft cased Francis Turbine for operation under a head of 90 ft. This machine has recently been built for electric power generation at a Tea Factory in Ceylon.



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AND COMPLETE HYDRO-ELECTRIC INSTALLATIONS

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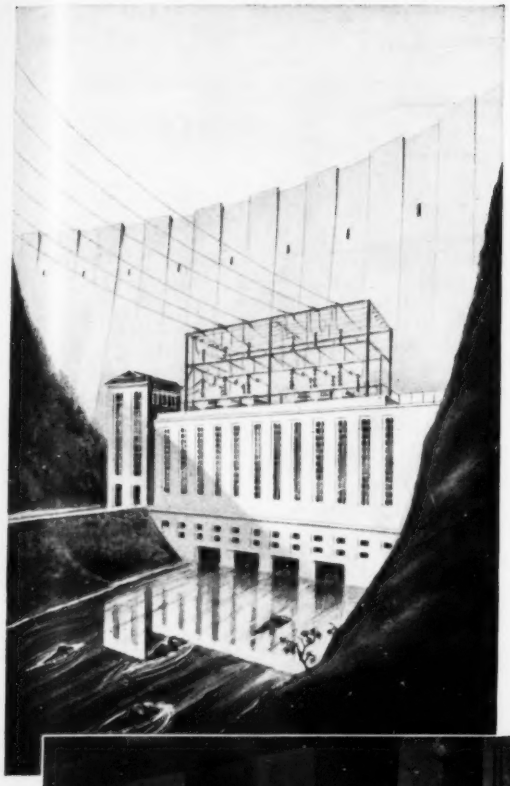
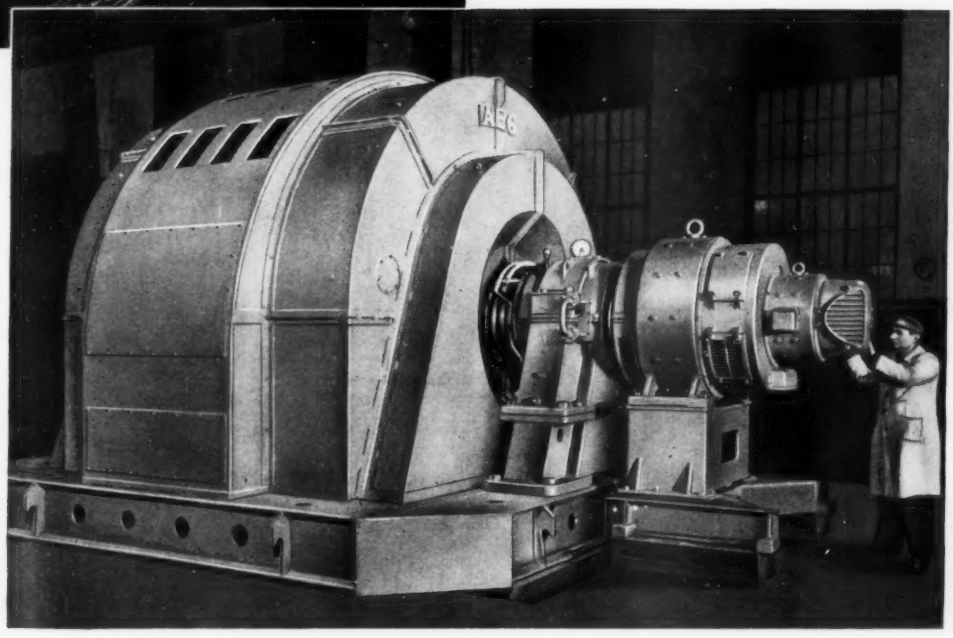


AEG
Water-Wheel Generators



24000 kVA, 600 rpm Generator on the test bed

60 YEARS' Experience in Hydro-Electric Plants

5376

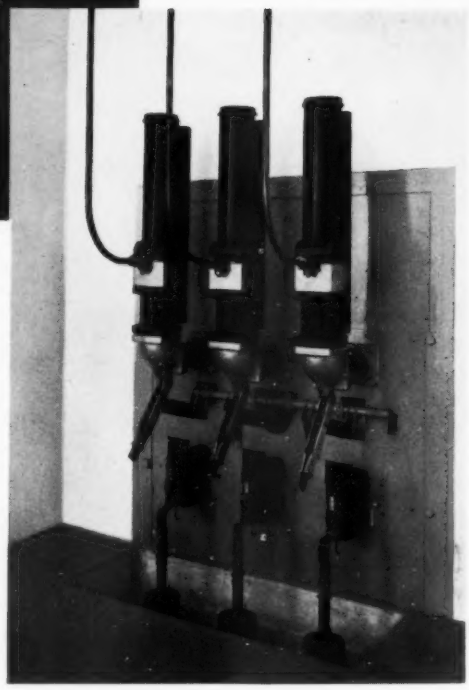
ALLGEMEINE ELEKTRICITÄTS - GESELLSCHAFT

Berlin-Grunewald — Export Department — Frankfurt a. M.

BROWN BOVERI

AIR-BLAST HIGH-SPEED CIRCUIT-BREAKERS

Left-hand illustration: Air-blast high-speed circuit-breaker type DB for 20 kV, 1000 A, 1000 MVA, seen from the operating side. The high-voltage and operating sides are separated by a panel. Each circuit-breaker can be operated by hand from the inspection gangway. The position of the isolating switch is indicated mechanically.



Indoor-type air-blast high-speed circuit-breakers

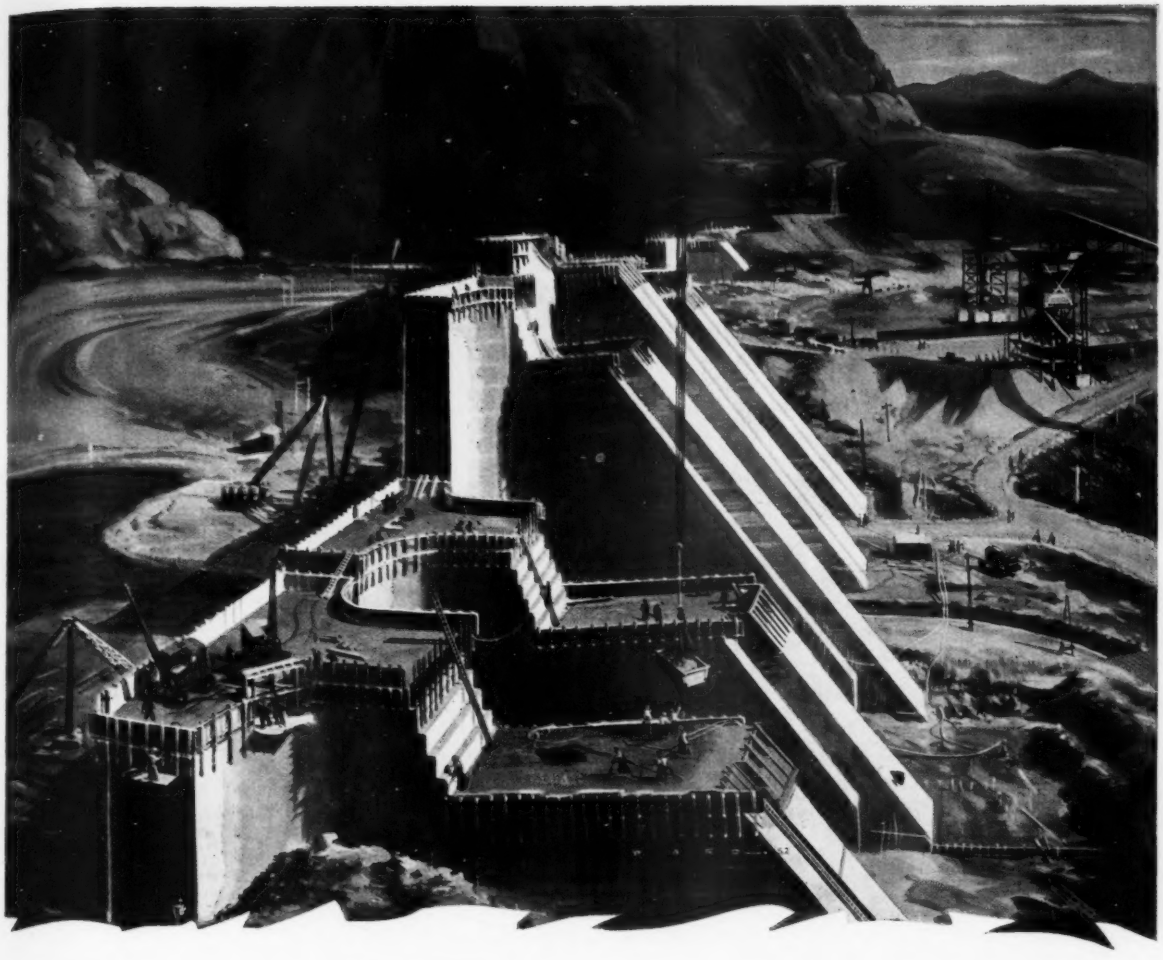
up to 60 kV, 4000 A, and 2000 MVA

- **Oil-less**
- **Short break time**
- **High-speed reclosing**
- **Minimum contact erosion**
- **Always ready for service, even after heavy-duty interruptions**

Right-hand illustration: Same breaker as above, but seen from the high-voltage side. The simple arrangement of the conductors and visible position indication of the contacts can be clearly seen.

Over 18,000 air-blast high-speed circuit-breakers have been ordered to date, of which the greater number has been in service for many years past

BROWN, BOVERI & CO., LTD., BADEN (SWITZERLAND)



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CP has given a new meaning to air power—air power which means victory over natural obstacles on the huge projects undertaken by the modern civil engineer. CP compressors, both stationary and portable, provide that air power with unequalled reliability and efficiency . . . CP breakers . . . CP pumps . . . vibrators . . . concrete breakers . . . picks . . . ancillary tools—extract every ounce of energy from compressed air. From the initial site preparation to the last nut and bolt—CP serves the civil engineer.

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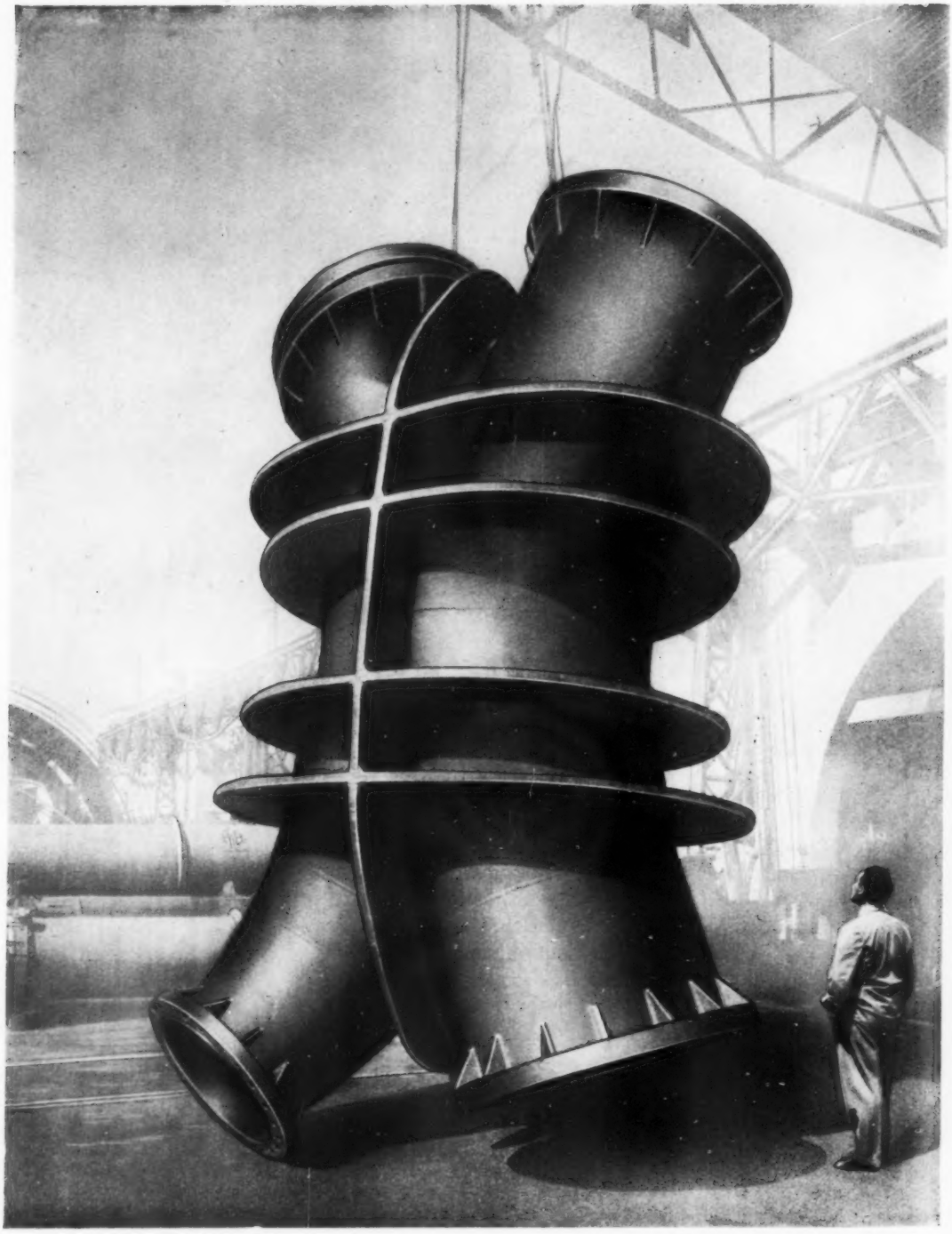
PENSTOCKS FOR HIGH-CAPACITY POWER SCHEMES



Four-forked piece made of welded steel plate for the "Volturno" Hydro-Electric Plant, Italy

ACCIAIERIA E TUBIFICIO DI BRESCIA BRESCIA (ITALY)

FORMERLY

TUBI TOGNI

the lonesomest plant in Puerto Rico

Although Caonillas No. 1 is a busy plant—producing up to 22,000 kva, and running full blast—you seldom see a man in it. Completely automatic operation makes it the lonesomest plant in Puerto Rico.

There's not even a man around to check on operation. That's done by remote control 10 miles away at Dos Bocas power plant—nerve center for three stations of the Caonillas Hydro-electric Project which supplies power to all points in Puerto Rico. At Dos Bocas, operators can tell by a glance at the Westinghouse control panel what is happening at Caonillas No. 1.

Sixteen billion gallons of water for this station are stored behind a concrete dam built across Caonillas River. It's a straight gravity overflow type dam, 850 feet long at the crest, and 250 feet above river bed. A pressure tunnel conveys impounded water through solid rock to No. 1 power house 2½ miles downstream, where two Westinghouse vertical waterwheel generators produce inexpensive power for transmission to thriving San Juan, and for irrigation and standby service.

Caonillas project, conceived and built entirely by Puerto Rico Water Resources Authority under the general direction of Antonio Lucchetti, Executive Director, adds vital new output to the Authority's expanding electrical network. Working directly with Authority engineers, Westinghouse was able to apply broad technical knowledge and manufacturing skill in designing hydroelectric plants and remote control.

Two Westinghouse vertical waterwheel generators similar to this unit were installed at Caonillas—each 11,000 kva, 3-phase, 60-cycle, 4160 volts, 514 rpm. Westinghouse builds both vertical and horizontal types, in practically all frequencies, speeds and voltages. For further information on power generating and distributing apparatus write to Dept. Y.

YOU CAN BE **SURE** ...IF IT'S

Westinghouse

WESTINGHOUSE ELECTRIC INTERNATIONAL COMPANY

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RAPIER

Water Control Gates

SUKKUR BARRAGE · RIVER INDUS

The Sukkur Barrage on the River Indus, Pakistan, is nearly a mile long and includes 66 RapieR Barrage Gates, each 60 feet span for flood control.

Each of the seven main Canal Head Regulators consists of a series of 3-tier Gates provided with Electric Operating Gates.

Altogether nearly 600 RapieR Gates are employed in this vast project controlling a 5,000 mile canal system providing irrigation for 8,000 square miles.

We are now building gates for the new Kotri Barrage 200 miles farther down-stream—a repeat order after 20 years' experience of the Sukkur installation.

ONE OF THE SEVEN MAIN CANAL HEAD REGULATORS

- *RIVER CONTROL*
- *IRRIGATION*
- *POWER PLANTS*
- *WATER SUPPLY*
- *LOCKS & DOCKS*

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WATER CONTROL
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RANSOMES & RAPIER LTD. ENGLAND

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NATURAL
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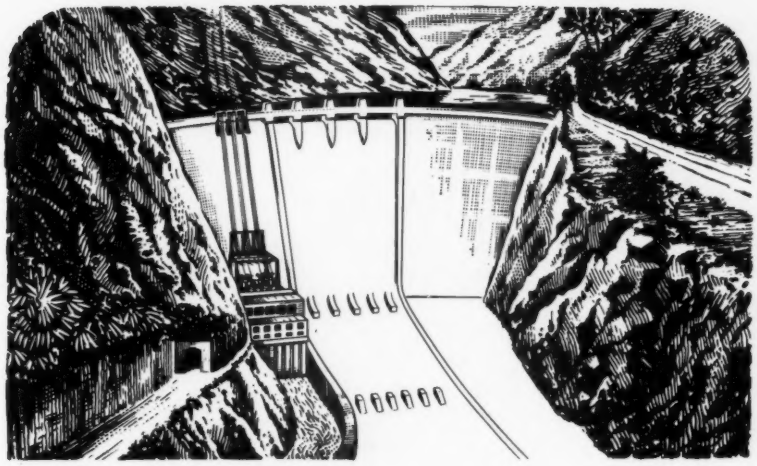
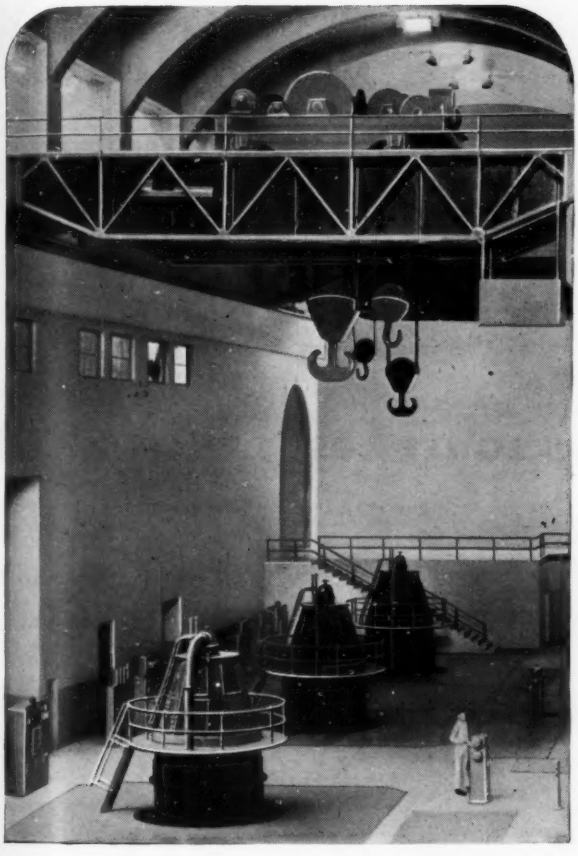


Hydro-electric Equipment



A natural source of perpetual power lies in the upland lakes and rivers of almost all countries. To harness it, BTH supply all plant required for hydro-electric power schemes. The long experience of hydro-electric engineering possessed by BTH is one reason for the superiority of their equipment. Another is the exceptional capacity of the Rugby works, where plant on a very large scale, such as is required for many hydro-electric schemes, can be built without restriction.

Top: Artist's impression of the Los Peares Power Station, North West Spain.

Left: View of a model of the interior of the above Power Station showing the exciter casings of the three BTH vertical waterwheel-driven alternators which will have a total output of 187,200 kVA.

For all plant required for Hydro-electric Power Schemes — **Consult BTH.**

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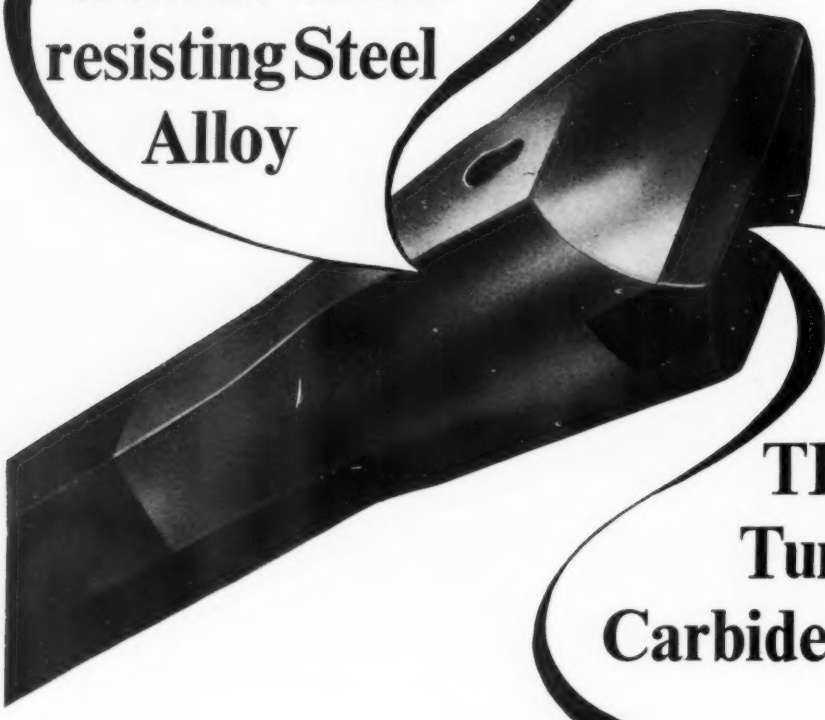

..and THIS Victor Tungsten Carbide insert

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ALL VICTOR'S 20 years' experience in the manufacture of tungsten tipped rotary drilling bits has gone into the development of these new drill steels. They have stood up to performance tests as tough as we can make them and are now ready to take their place in the world famous range of Victor mining tools.

NOW MAKING THEIR MARK IN DRILLING

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THE NEW

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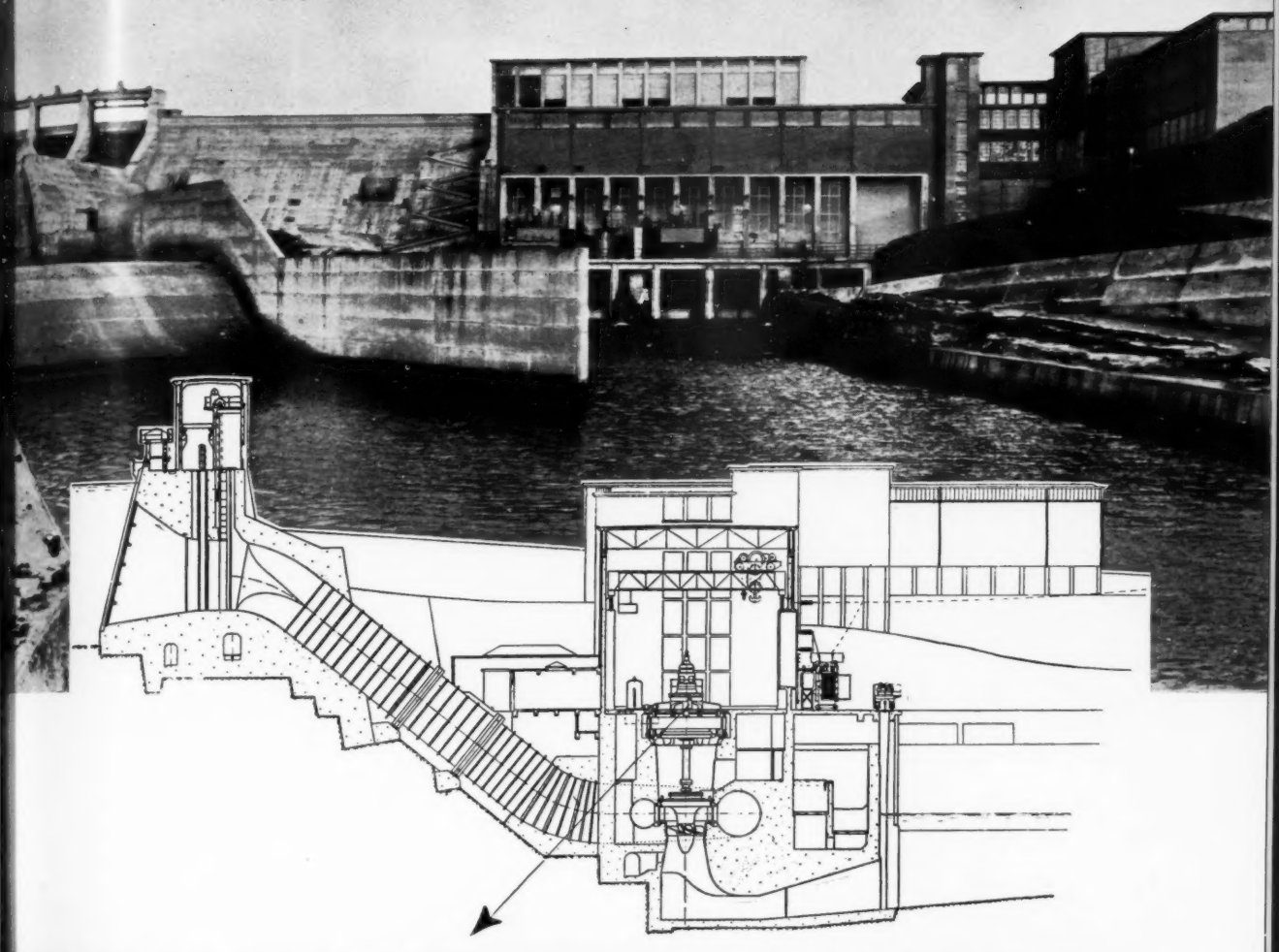
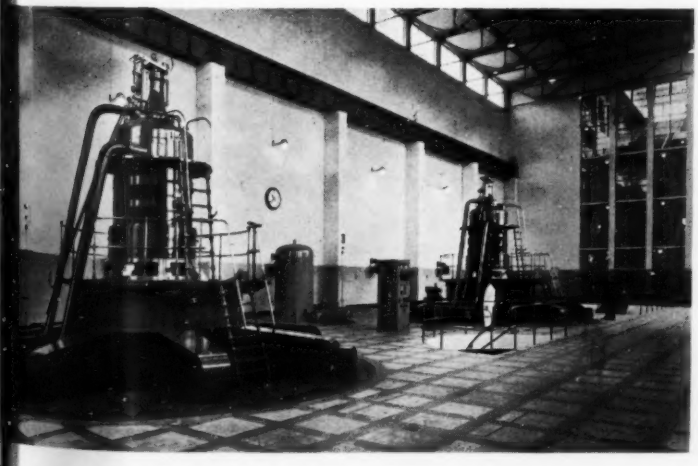
DRILL STEEL

SEND FOR DETAILS — NOW!

CATHALEEN'S FALL STATION

Electricity Supply Board, Dublin, Eire





KMW

Two Kaplan turbines each developing 31,700 H.P. at 28·2 metres head and 187·5 r.p.m. One house turbine of 580 H.P.

Turbines and Governors delivered by

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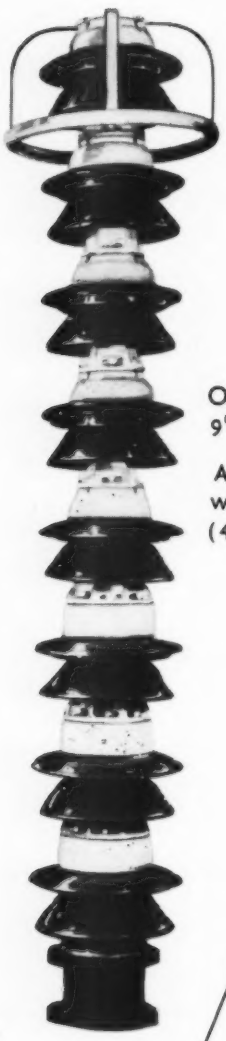
KARLSTAD • SWEDEN



275 kV POST INSULATOR for the *NEW* BRITISH SUPER GRID ....

Overall height 9' 8" (2.95 m)

Approximate weight 1,000 lbs. (455 kg)

The result of extensive tests and research.. T.T. insulation takes another step forward.

In front as usual, Taylor Tunnicliff are ready to make another contribution to the NEW 275 kV Super Grid soon to take its place in the electrical supply organisation of Great Britain. Meticulous research, exhaustive and rigorous tests, skilful craftsmanship and long manufacturing experience put this latest product of the Taylor Tunnicliff organisation at the top of its class.

Taylor Tunnicliff & Co. Ltd.

Makers of High Voltage Porcelain Insulators used all over the world

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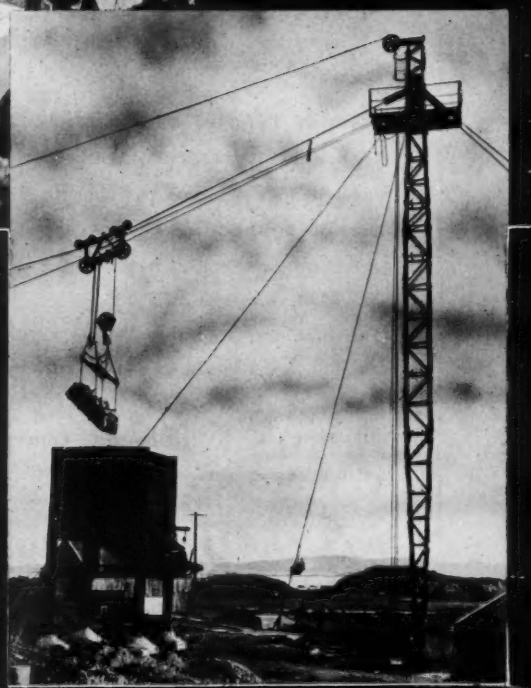
ESSENTIAL FOR DAM CONSTRUCTION



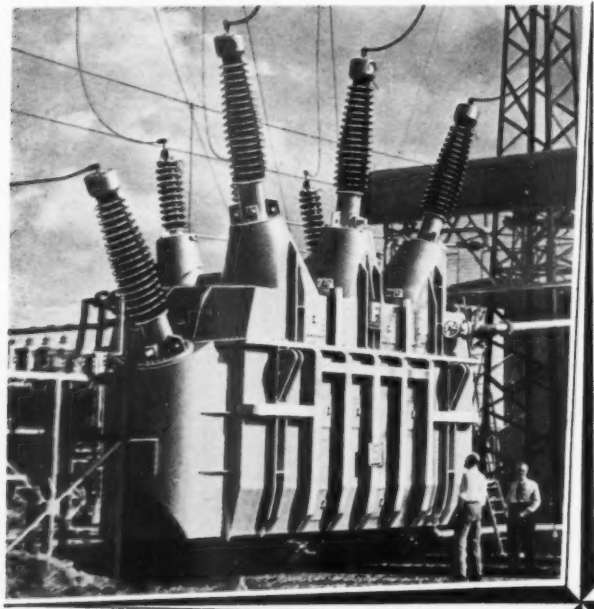
Giant hydro-electric schemes in all parts of the world make use of BRECO Aerial Ropeways and Cableways.

One of the largest builders of heavy capacity Ropeways and Cableways in the world, BRECO will supply advice and technical information willingly, and without obligation.

BRECO *Aerial* ROPEWAYS

BRITISH ROPEWAY ENGINEERING CO LTD PLANTATION HOUSE MINCING LANE LONDON E.C.3

FERRANTI *in the east and in the west*



FINLAND

PYHÄKOSKI GENERATING STATION

Five Ferranti 230 kV three-phase transformers for the Imatra Power Company, Finland, were the first 230 kV three-phase transformers to be ordered in Great Britain. Each transformer is rated at 64/64/32 MVA, 231/115.5/10.5 kV, and has a total weight with cooling gear 220 tons.

Opposite: One of the completed transformers in commission at the Pyhäkoski Generating Station.

UNITED STATES

GARRISON DAM PROJECT

N. DAKOTA

Through Ferranti Electric Inc., New York, the Ferranti organisation has secured in open competition the contract to supply the U.S. Army Corps of Engineers with nine single-phase 13.2/230 kV, 33,333 kVA generator transformers, forming three 3-phase 100,000 kVA banks, each bank connected to the 13.8 kV output of one 80,000 kVA hydroelectric generator with a maximum continuous rating of 97,800 kVA.

CANADA

ALCAN BRITISH COLUMBIA PROJECT

Ferranti transformers ordered for this project comprise four 71,000 kVA single-phase generator transformers forming a 213,000 kVA, 13,200/301,000 volt 3-phase bank at KEMANO and three 37,000 kVA, single-phase step-down transformers at KITIMAT, will form a 111,000 kVA, 275,000/13,200 volt 3-phase bank. The contract was secured against international competition.

HEAD OFFICE AND WORKS:

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FERRANTI—A FAMOUS NAME IN ELECTRICAL ENGINEERING FOR 70 YEARS

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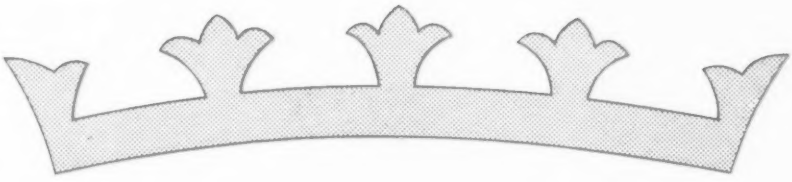


Long Live Elizabeth

May the years ahead be long and venturous . . . . may they see the fulfilment of many of our national aspirations. May they be years of peace and growing understanding among the nations.

May they be years of peace and reconciliation within our own economy.

May they be years of progress . . . . not only in our twentieth century techniques, but towards a higher idealism. May they be years of plenty . . . . a plenty in which we all share, and which we share with all.

Long Live Elizabeth

May we, too, play our part.

Issued in reaffirmation of our common loyalty by **HUGH WOOD & CO. LTD.**

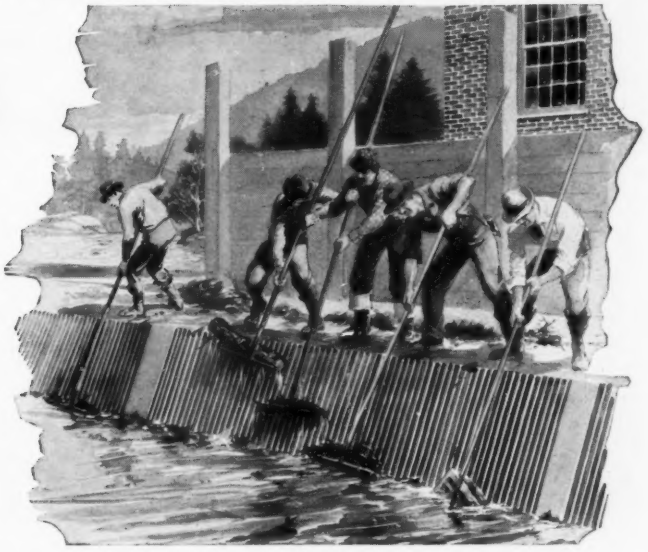
ALTERNATORS
for Hydro-Electric Power Stations

Mounting in our Works of a new 30,000 kVA - 6,600 Volts - 333 R.P.M. vertical-shaft alternator. This machine will equip the DELCOMMUNE Power Station, N'zilo Falls, and will contribute, with two other identical Units now under construction, to the industrial development of the Belgian Congo.

ATELIERS DE CONSTRUCTIONS ÉLECTRIQUES DE CHARLEROI

CHARLEROI CAEC

Save COSTS *and* Cut LOSSES *with the* LEONARD Trash Rack Rake



MAKE MONEY by saving it! These pictures tell the story - how back-breaking work is eliminated and Racks kept clearer of leaves and other debris, by the use of this simple device which automatically assures higher turbine or pump performance. Write for Bulletin 146 - now!

The Harland Engineering Co. Ltd., Alloa, Scotland
Manufacturing Licensees for the British Commonwealth

If It's Hydraulics~ Put It Up to Us!

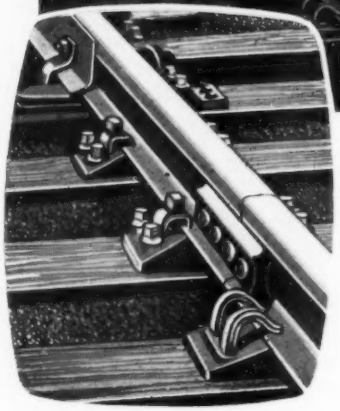
S. MORGAN SMITH Co.
YORK, PENNA. U.S.A.

SIDINGS by WARDS

A WARD-BUILT RAILWAY SIDING doesn't just happen. Rather is it the result of skilful planning allied to sound railway technique.

Wards have been building sidings for a variety of operating conditions for almost half a century and thus bring to the subject an extensive knowledge of every aspect of railway siding planning, construction and maintenance for industrial usage.

Those who are concerned with the operation and maintenance of private railway sidings will find much useful information in the second edition of our booklet "Rails and Rail Accessories." Copies forwarded on request.



109 lb. F.B. rails are used throughout this siding. The inset shows the detail of fastenings for this type of rail.

The Railway Siding Consultants and Contractors

THOS. W. WARD LTD

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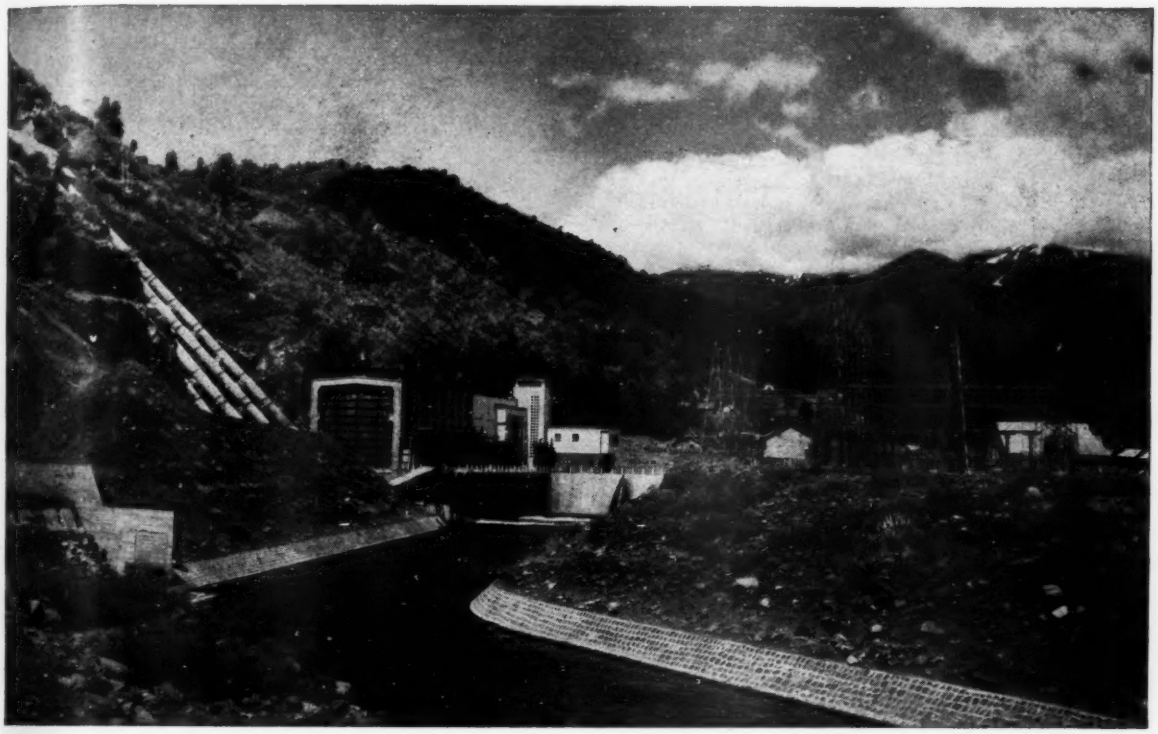
SC125

New Power From Chile's Glacial Watersheds!



Chile is building a series of hydro-electric stations to provide sources of inexpensive power for industry and transportation, utilizing glacial watersheds in the Andes. The first two stations to be built and put in operation were Abanico and Pilmaiquen. Chilean engineers surveyed their country's potentialities . . . picked sites for development at the lowest cost and greatest efficiency. Then G-E engineers teamed with Chilean engineers, gathered data on the spot, designed, built and tested the electrical equipment.

These hydro-electric stations are one example of G-E installations located throughout the world.

EQUIPMENT INSTALLED General Electric equipment installed at Abanico and Pilmaiquen consists of generators, switchgear, control, transformers. Abanico's four 21,500-kva water wheel-driven generators now produce 86,000-kva at 13,200 volts, 50 cycles. This is stepped up to 154,000 volts for transmission. Part of this power supplies the new Huachipato steel mill, also G-E equipped.

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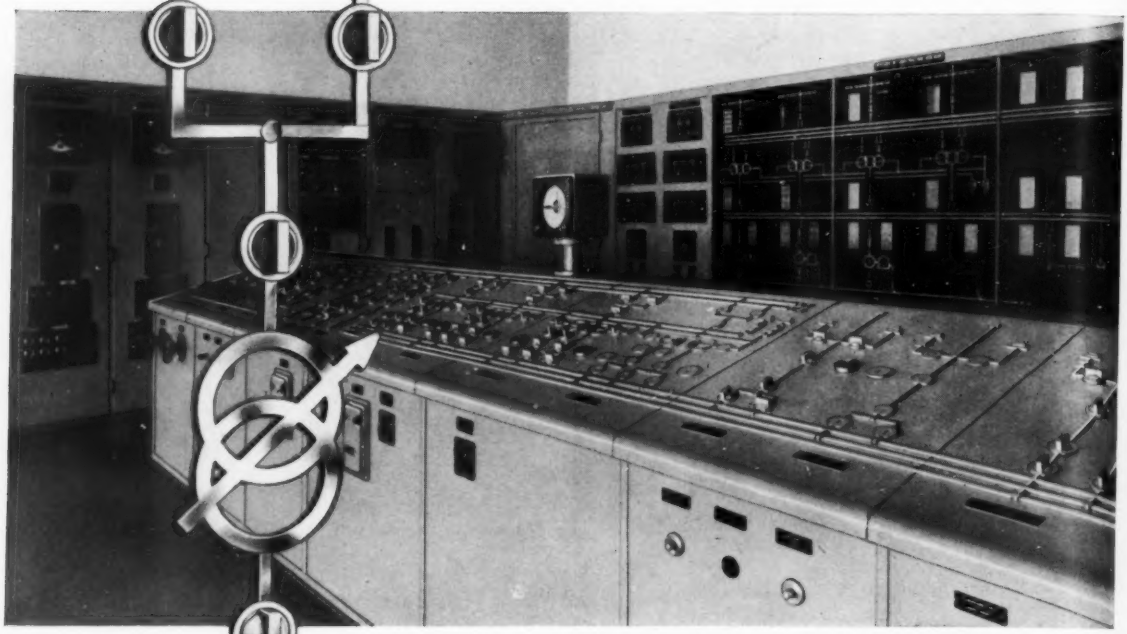

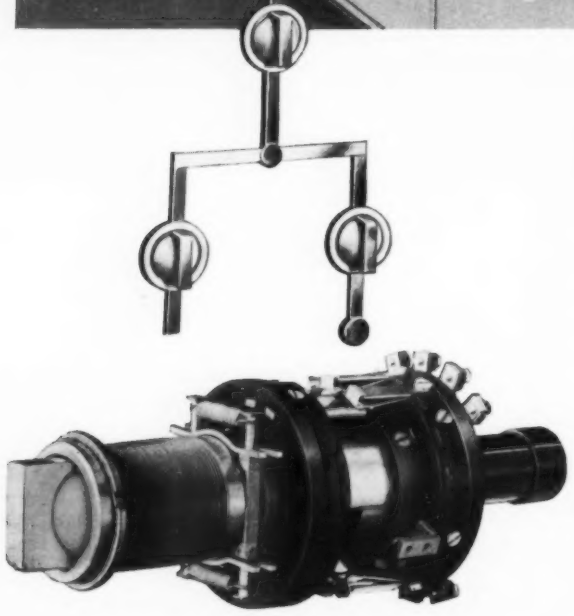

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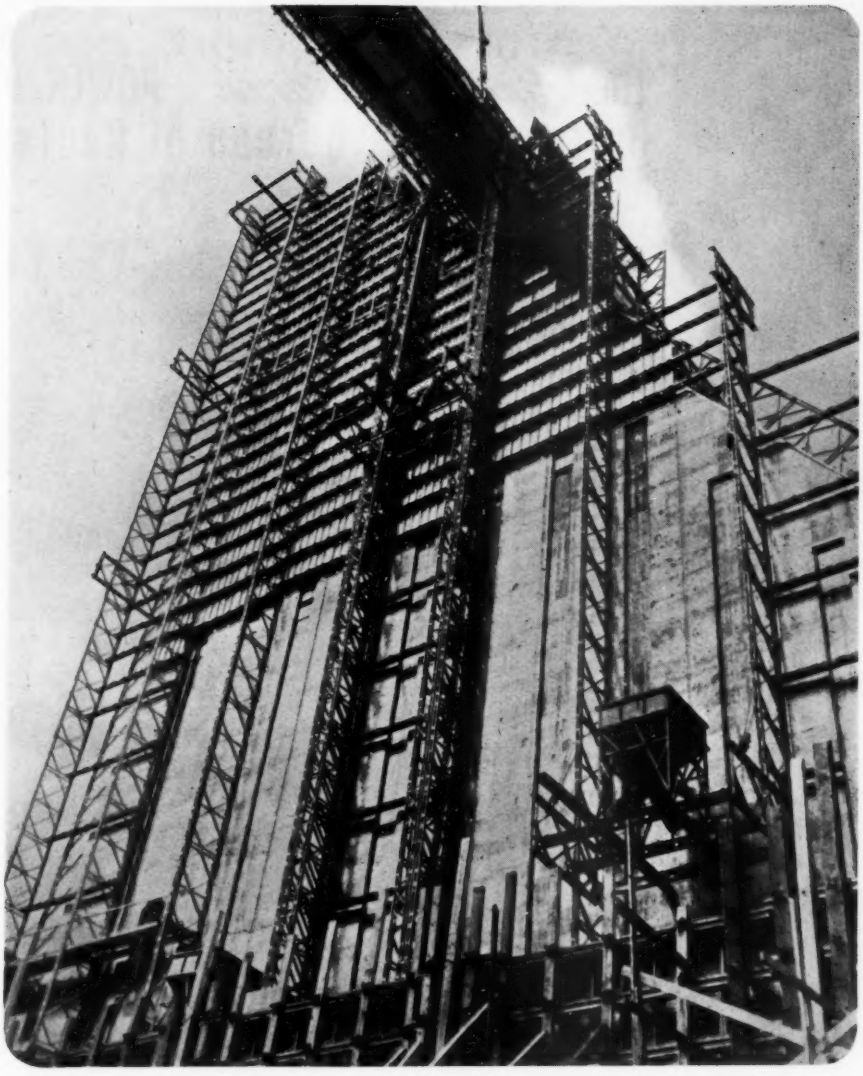

Photograph by courtesy of the Ontario Hydro Electric Commission

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The *"Anderson Ranch"* POWER PROJECT
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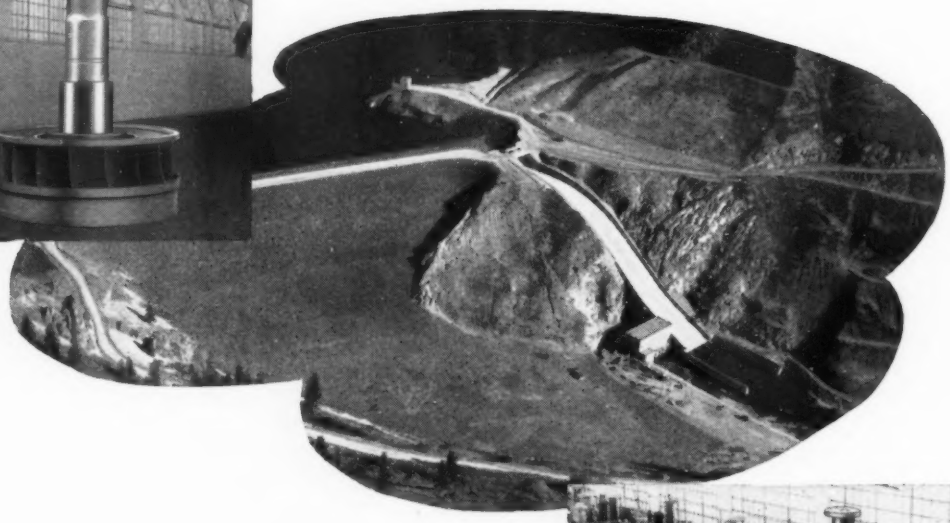

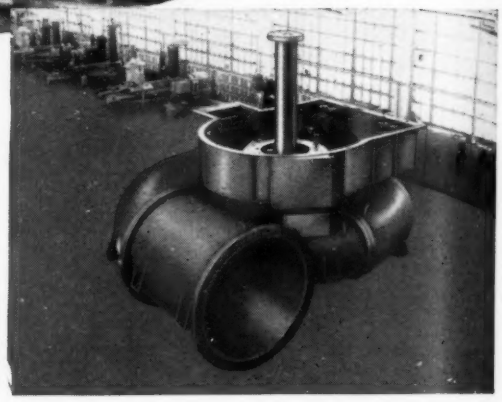

hydraulic turbines by **LEFFEL**

Anderson Ranch Dam, located on the Boise River in Idaho, U.S.A., is the highest earth-fill dam in the world. Two Leffel Turbines are installed in the Anderson Power Plant which provides power for the surrounding area. The turbines are of the cast steel spiral case, vertical Francis type and each is maximum rated at 28,250 HP, under 324 ft. net head, speed 277 RPM.

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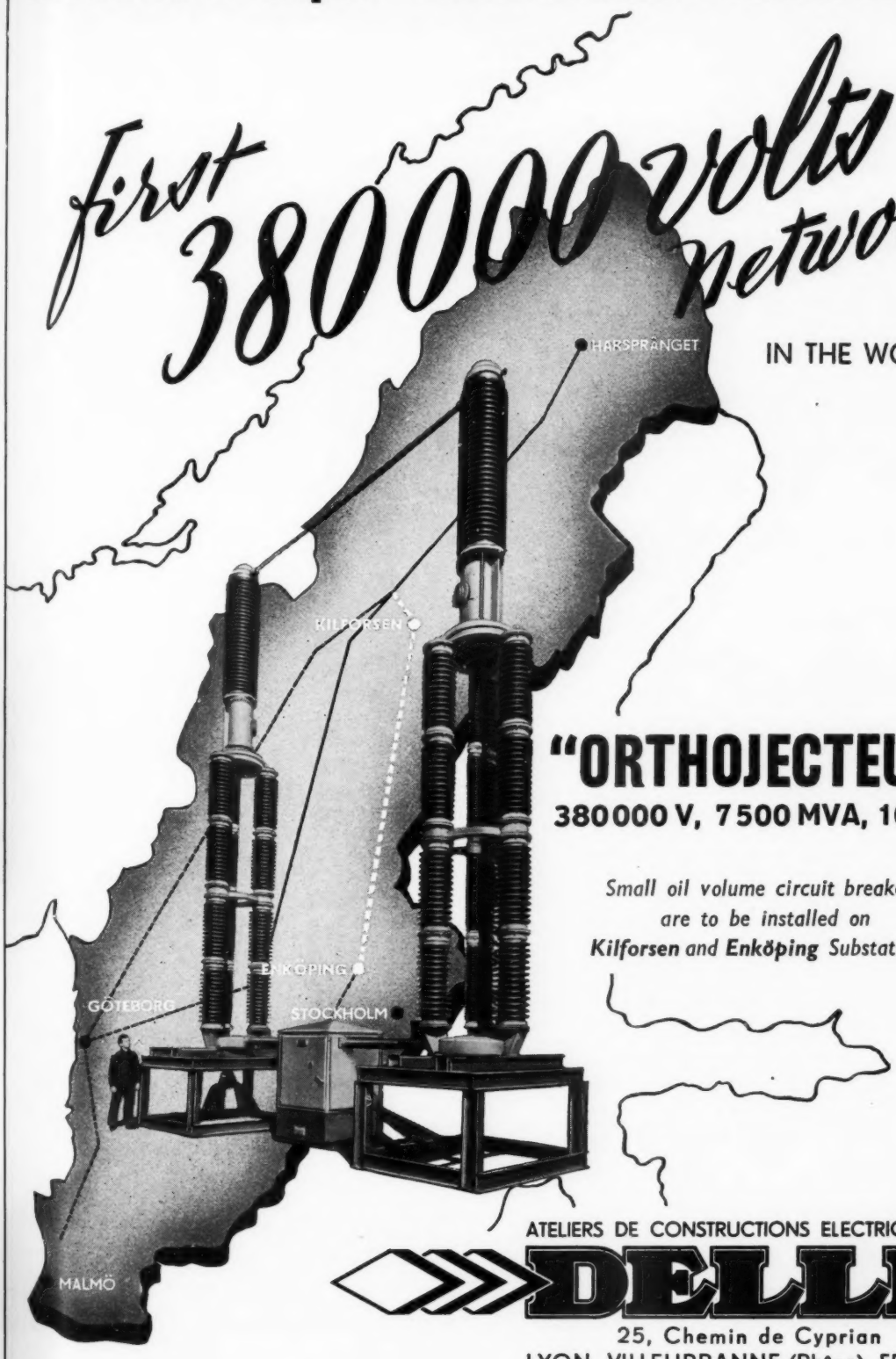

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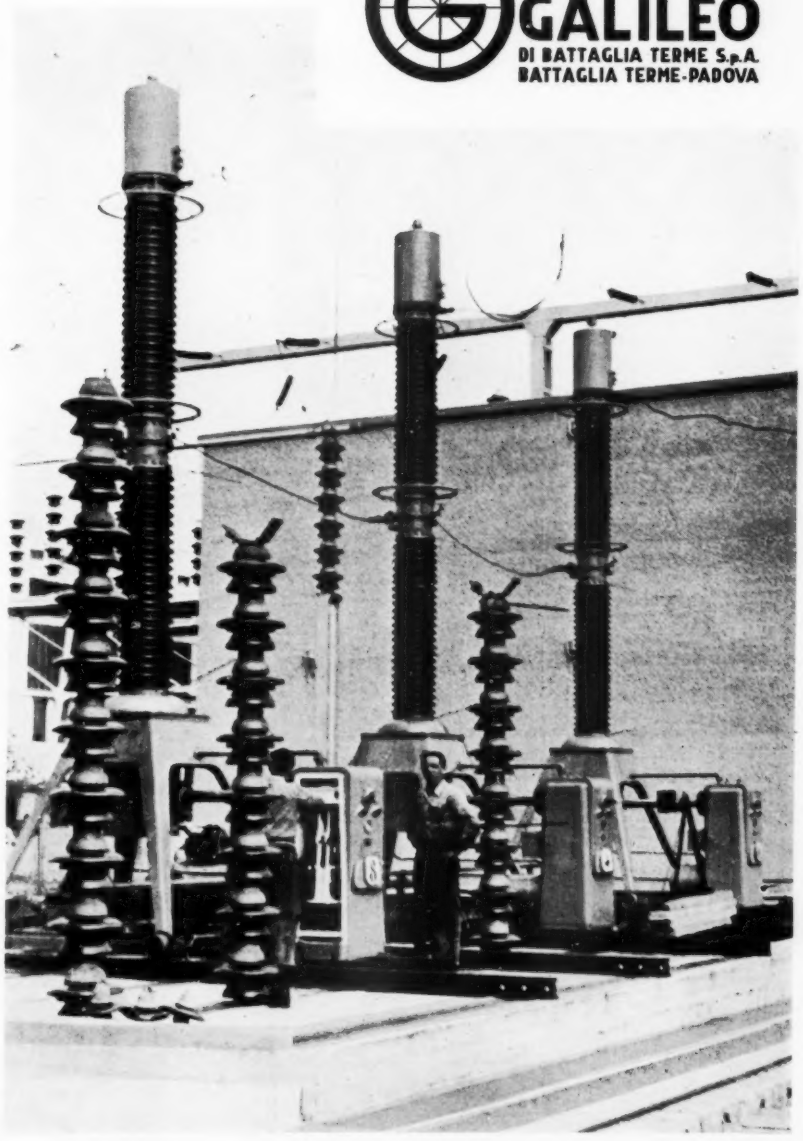

The illustration shows :
Switchgear type OCERD 220 photographed during a test for maximum load, made with favourable results at the test station of Messrs. Eléctricité de France at Fontenay aux Roses (Paris).

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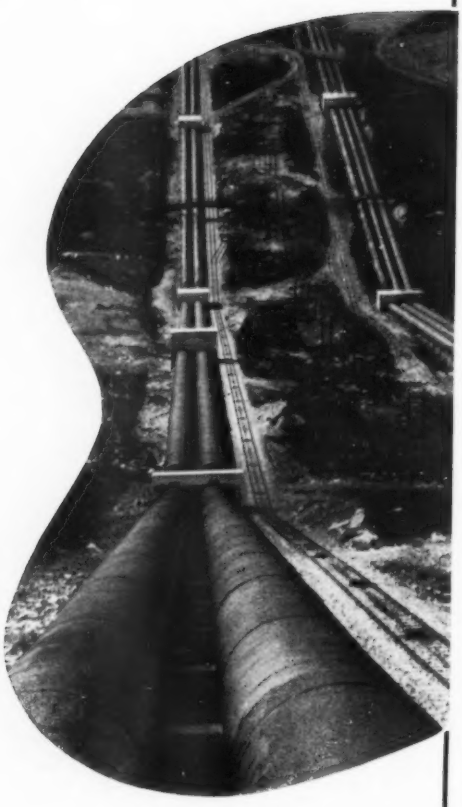

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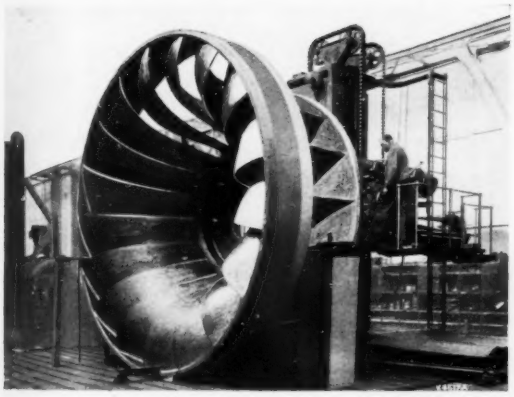
On the left: 34,600 H.P., Hirakud II (India)

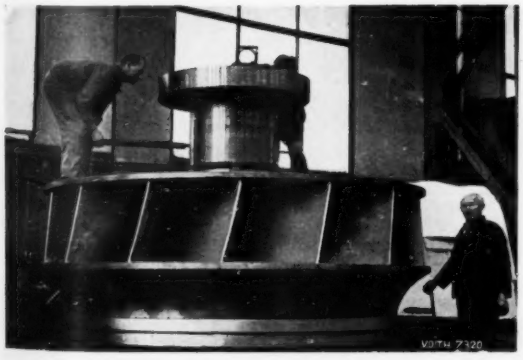
Below: Runner 15 feet diameter, 115,500 H.P., Sungari (Manchuria)

On the right: 52,400 H.P., Cipreses (Chile)

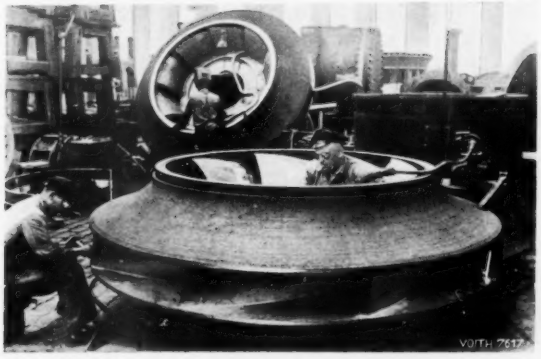
Below: Split runner 16′ 5″ diameter, 60,000 H.P., Parahyba (Brazil)

In the foreground: the runner model





Runner 60,000 H.P. output, Waldshut (Germany)



Storage Pump Impeller 24,100 H.P. input, Waldshut

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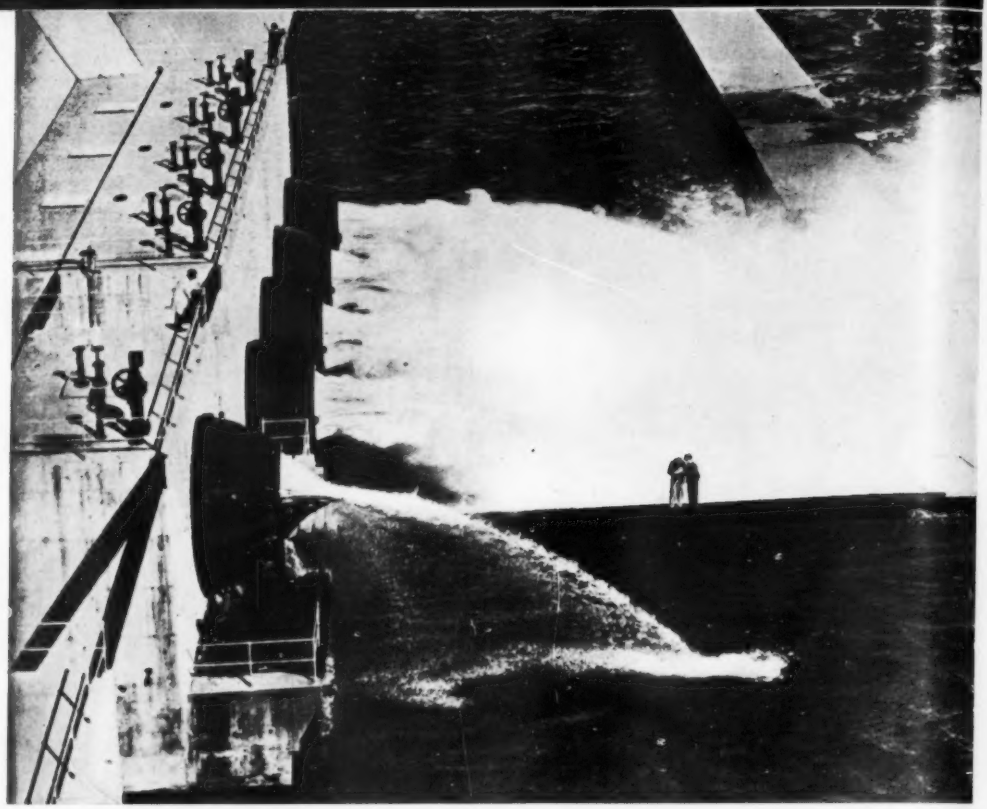

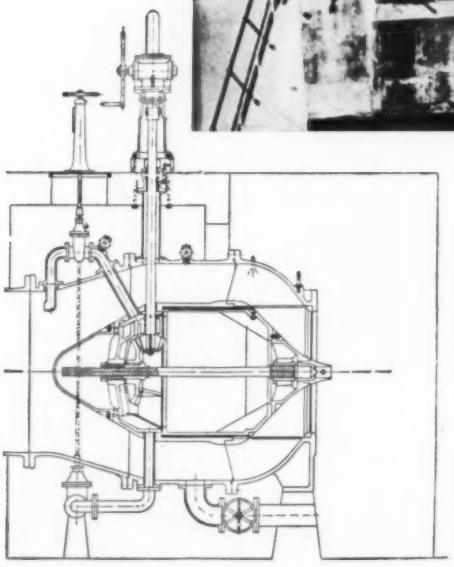

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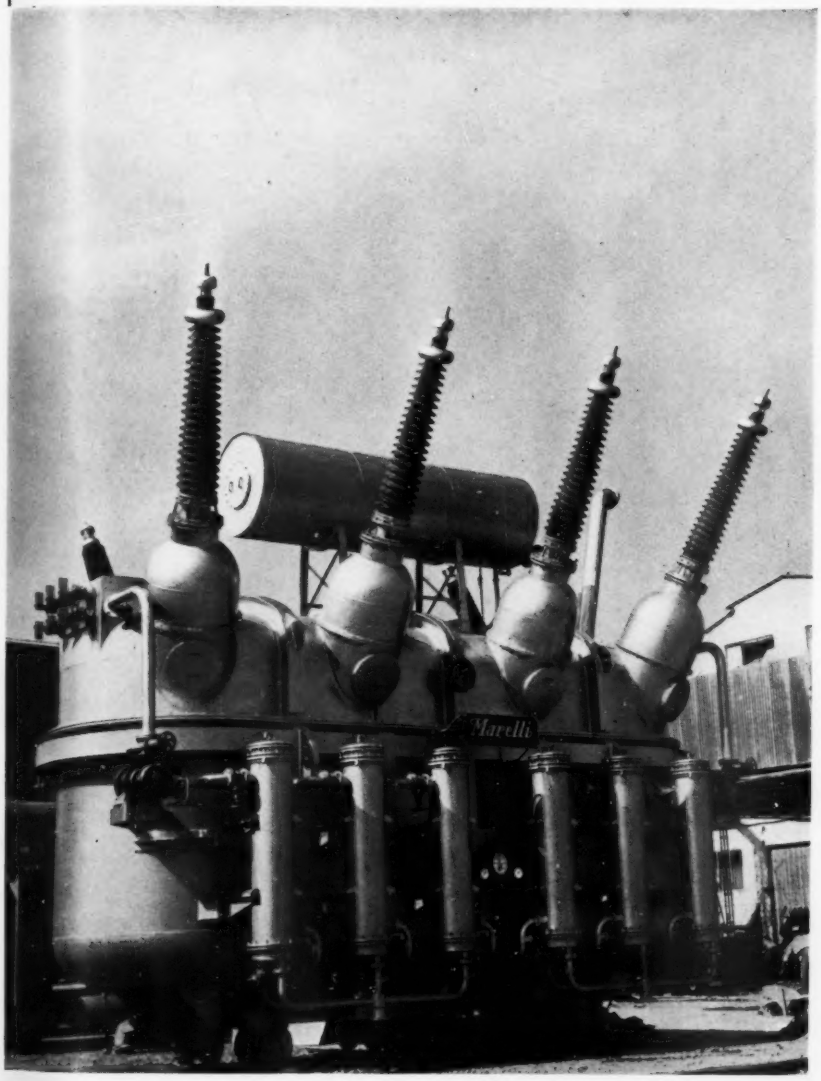

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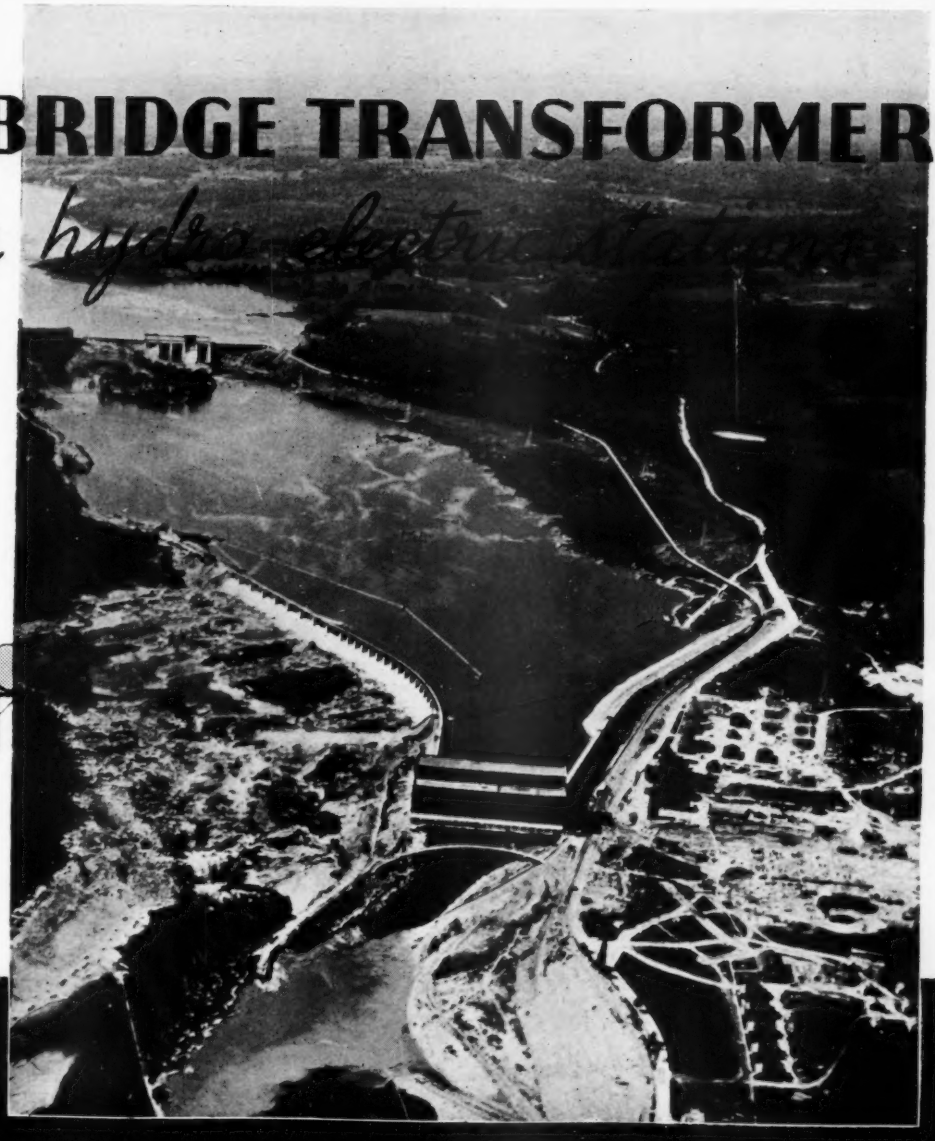

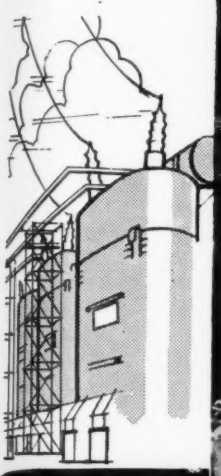

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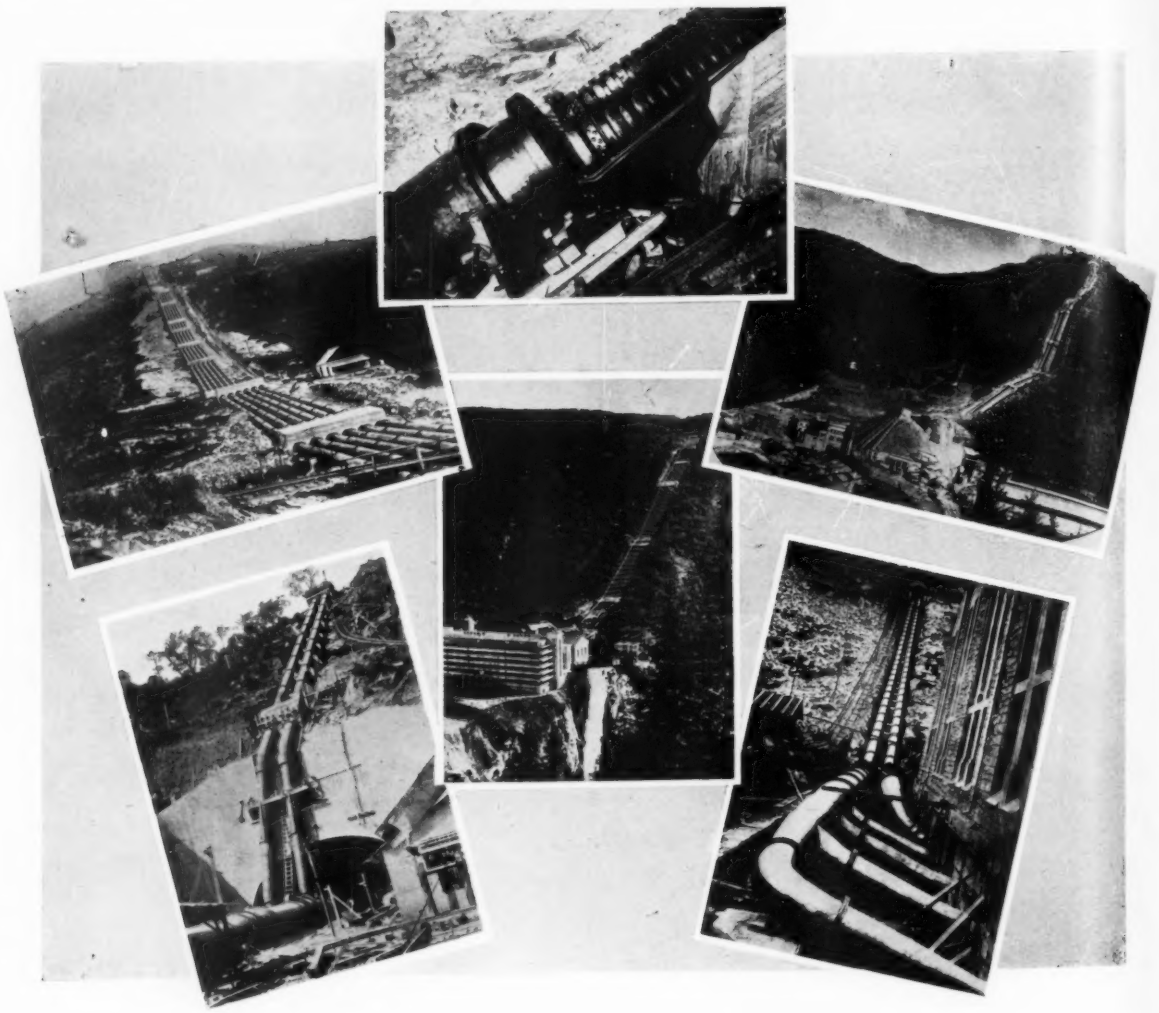

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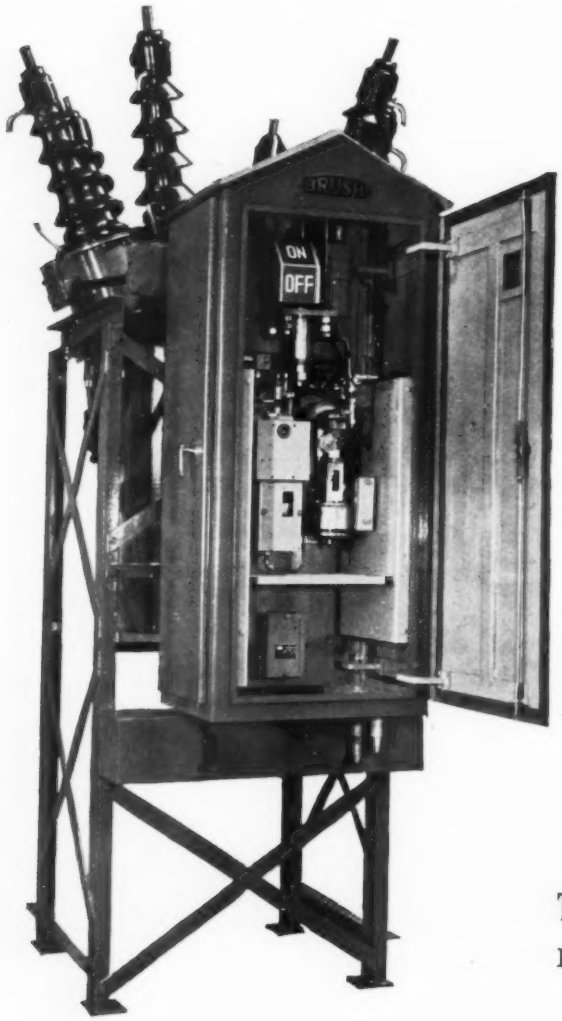

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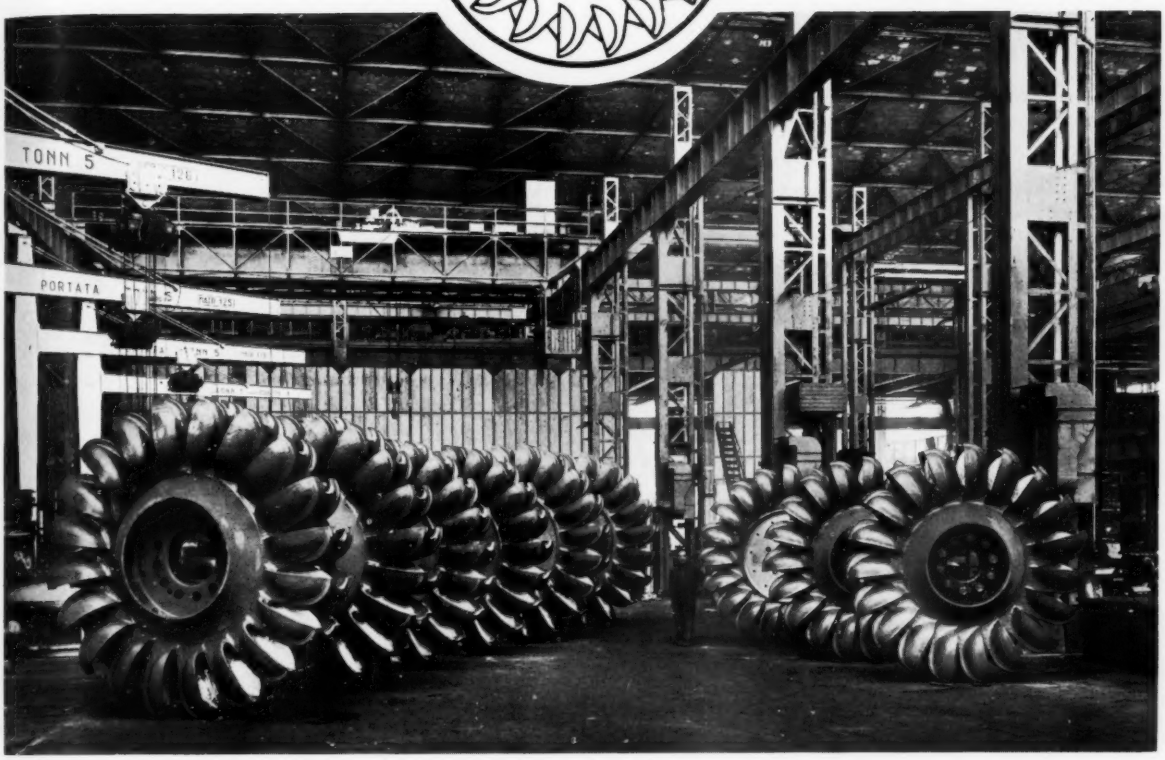

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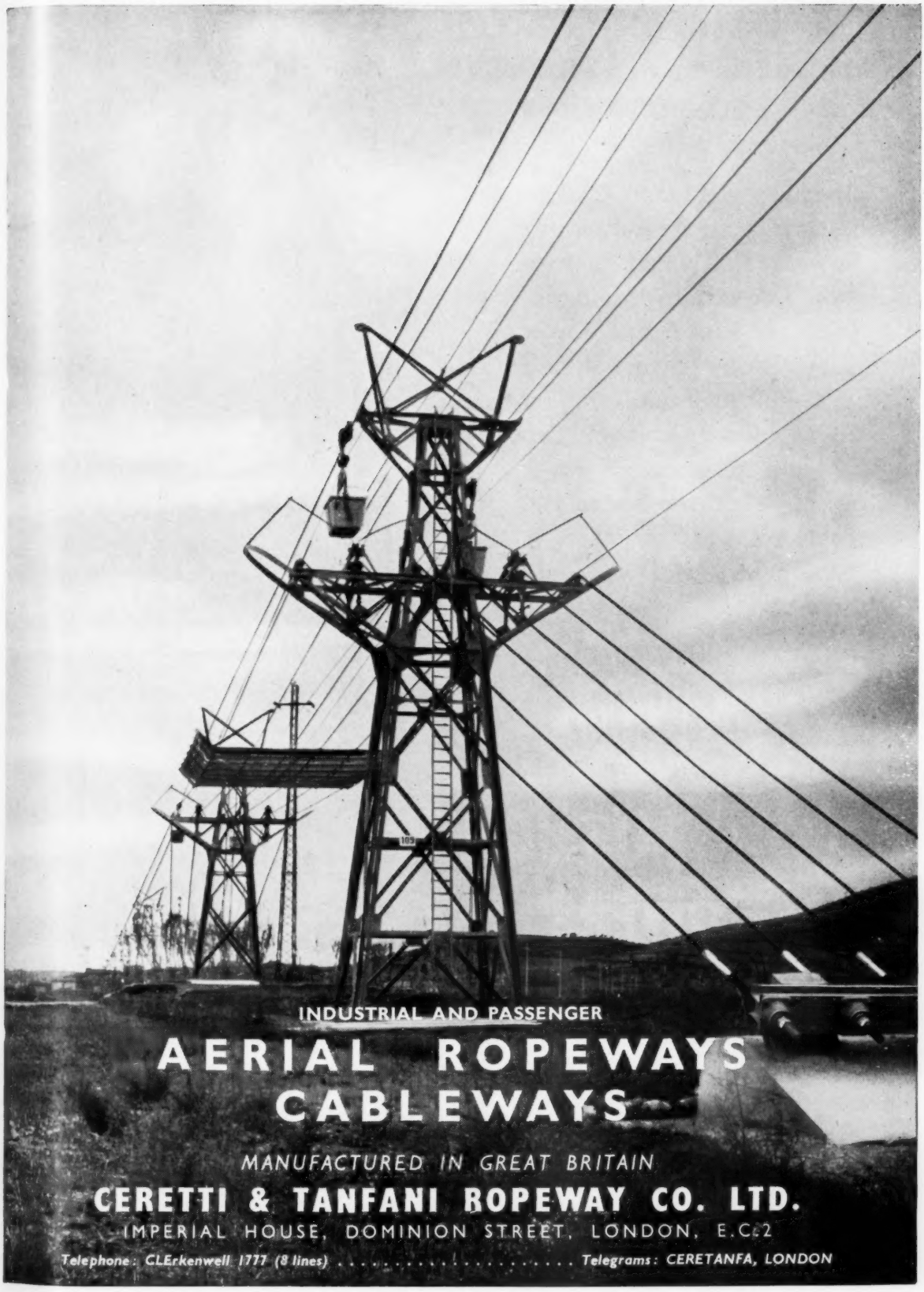
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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

System Stability

THIS is an era of ever-increasing development in the transmission of electrical energy in almost every country in the world. Remote hydro-electric sites are being harnessed, and distances of 400, 500 and even 600 miles are spanned by high-voltage transmission lines in order to bring their outputs to the centres of load. American opinion, expressed in the last few months by several of the leading transmission experts, has indicated that the traditional outlook of independent power pools in the vast territories of the United States may soon give way to a new philosophy of national interconnection, just as it did in Great Britain and France, as well as in other industrial countries.

The basic problem in all transmission matters is that of system stability. The transmission specialists have various cures for unstable conditions such as the provision of series capacitors and other compensating equipment, and the possibility of the use of d.c. for long-distance transmission of energy. But these measures cannot be efficient unless there is basic stability at the generating source. In the case of thermal stations, with high-speed turbines, there is little remaining to be done in the way of increasing the stability of the generating units, but in hydro-electric power plants the situation is different. Small draught-tube surges may still cause large power swings, and with the possible exception of the few plants fitted with electronic-hydraulic governors, governing is still not as sensitive as in the case of steam-turbine governing equipment.

Draught-tube and other surges, of course, do not apply to all turbine designs, but in many cases a cumulative effect is caused by fluctuations in draught-tube vacuum, which in turn cause fluctuations in the effective head on the turbine and thus a change in the discharge volume. In long penstocks, this set of conditions may cause an amplitude of fluctuation possibly reaching serious proportions.

It is therefore not surprising that much research has been carried out towards improving the stability of hydro-electric generating units in recent years. Attention has been focused on the provision of better electrical damping on the alternator, although there is more than one opinion as to the efficiency of this solution. A Swiss proposal has been to devote great attention to stabilising the water level upstream of hydro-electric stations by an extremely sensitive control of the electrical loading in relation to the hydraulic loading. In some cases this implies alterations to the design of the surge chamber, generally in the direction of increasing its size. We look forward to hearing in due course of the results of lengthy tests, which are being carried out under the direction of the hydraulic laboratory of the Ecole Polytechnique de Lausanne, on the type of control system where the electrical output is made to be dependent on the upstream water level.

Other workers in this field are devoting their attention to closer control of the excitation and voltage output of hydro-electric alternators. A compromise between voltage systems suitable for exact second-by-second regulation of the voltage to within a very small fraction of a predetermined figure, and other systems which do not provide this feature but which give protection against the kind of power swings leading to system instability, appears to represent present progress in tackling this particular problem.

There is also much discussion in hydraulic design offices on the choice of characteristic constants for hydro-electric alternators. The conflicting claims on the one hand of economy in first cost, and on the other of achieving optimum operating characteristics mean that different manufacturers have different ideas as to the moments of inertia, the acceleration constants, the permissible runaway speeds and similar values, for different classes of generating plant.

The problems inherent in governing and controlling the very large masses involved in the design of rotors and runners for hydro-electric sets of over 100 MW in individual capacity are obviously difficult of solution, since any governing mechanism cannot be of a light and sensitive nature in itself, even though the initiating impulses from the corrective equipment are instantaneously transferred to the first of a series of servo-mechanisms. The development of power-

operated thrustors for very large aircraft, in which instantaneous response is expected, may perhaps result ultimately in the hydro-electric engineer being provided with devices of a sensitivity hitherto unknown in his field.

Whatever solution to the problem of inherent stability of operation within the hydro-electric power house is ultimately adopted, there is little doubt that attention must be increasingly focused on this aspect of the operation of water-power systems.

Chief Joseph Dam Contract

ANY criticism of the peculiar position which has arisen about The English Electric Company's tender for part of the equipment for Chief Joseph dam can very well be left to the Americans themselves, and certainly criticism in that country has not been lacking. Admittedly the rejection of this tender, which, it is estimated, would have saved taxpayers in the United States about £1,500,000, is a rebuff to those dollar-starved nations which are striving to earn dollars rather than to receive them gratis, and there is a general feeling of dissatisfaction that this desirable objective is subject to so many uncertainties. On general principles the spectacle of a vast creditor nation hesitating to buy from a debtor customer is indeed a curious one and it is to be hoped that the controversy which has arisen will lead to some permanent good. Admittedly, an unemployment problem is a nightmare to the government of any country and presumably it is this consideration which prevents the United States from adopting a freer policy of imports. But experience has shown that trade within the western nations is now such a highly interrelated affair that all become involved if a severe recession takes place in any one. The problem of defence, in particular, concerns all alike, and the best defence surely consists of building up a healthy international trade which will redound to the prosperity of all. The significance of the Chief Joseph dam affair, indeed, is that it raises issues much further-reaching than the question of whether Great Britain gains or loses any particular contract.

Hydro-Electric Progress in Europe

ACCORDING to a recent study published by the United Nations Economic Commission for Europe under the title "Recent Developments in the Electric Power Situation in Europe, 1951-52," hydro capacity in Europe from 1938 to 1951 rose by 70 per cent. as compared with 40 per cent. for thermal capacity. Nevertheless the ratio of hydro to thermal production remained at 38 per cent. hydro to 62 per cent. thermal. Total hydro-electric production in Europe increased by 15 per cent. in 1951 compared with 1950, reaching a total of 129,000 million kWh.

Many European countries that have mainly depended on thermal power production until recent years are at present engaged in large-scale development of their hydro resources, for example, Albania, Bulgaria, Czechoslovakia, Greece, Portugal, Rumania, Turkey and Yugoslavia. There is a contrary tendency, however, in a few countries where hydro resources have already been exploited to a point at which maximum utilisation is in sight. In Italy, for example, it is expected that thermal power will slowly grow in importance. As a whole, Europe has still sufficient unharnessed hydro resources to continue a rapid increase of hydro production at least for the next 10 to 15 years.

As in previous years, trade in electricity in Europe during 1951 was mainly composed of power exchanges between hydro and thermal regions. Guaranteed supplies of electricity over the boundaries remained low. As a whole, electricity exports in 1951 represented 1·6 per cent. of the total electricity production of 340,000 million kWh, against 1·4 per cent. of 1950's total output of 303,000 million kWh. The increase was due to the favourable hydrological conditions in Continental Europe with greater exports of surplus power from the hydro countries to neighbouring thermal countries. East-West trade in electricity in 1951 was concentrated to the power exchange between Eastern and Western Germany and was maintained at about the same level as in previous years.

President Eisenhower and St. Lawrence Seaway

THE attitude of the United States Government to the St. Lawrence Seaway project was revealed by President Eisenhower at a recent press conference at which he stated that his Administration favoured American participation in the scheme. Failing approval by Congress, he considered that no obstacle should be placed in the way of its construction by Canada alone. The National Security Council had recommended the implementation of the scheme for security reasons.

It will be recalled that the project has been repeatedly rejected by Congress although it has had the approval of every President from Woodrow Wilson onwards, and that the Canadian Government last summer decided to proceed irrespective of American participation.

Snowy Mountains Tenders

THE Snowy Mountains Hydro-Electric Authority is calling for tenders for civil-engineering works for the second stage of this £46 million scheme. At the moment of writing the specifications have not yet been published, but we understand that three contracts are to be let, covering respectively the main tunnel from Adaminaby to Tumut Pond, Tumut Pond dam and T1 headrace tunnel, and the pressure shaft, power-station excavation and tailrace for T1 station. Tenders for the main generating sets for this station were called for some little time ago and are now under consideration.

Our concluding article on the Snowy Mountains scheme, which appears elsewhere in this issue, describes the progress made on the Guthega project, which forms the first stage of the scheme, and includes tentative drawings of the T1 station layout and electrical system.

Quebec Power Company

DURING 1952 the Quebec Power Company's capital expenditure rose to $1,883,182—the largest amount invested since the company was organised. Of this amount no less than $520,800 was spent on the Champlain substation in the St. Malo section of Quebec, which was placed in service in December and

will have an ultimate capacity of 40 MW. $959,625 was invested in the extension and improvement of the transmission and distribution system, and $227,164 in other new substations and extensions. The new 60 kV line from Ste. Anne de la Pocatiere to St. Pascal was completed and placed in service at the beginning of the year.

Sales of electricity increased by 9·1 per cent. to 562,500,000 kWh, of which the company's generating stations supplied 25·8 per cent., and there were 3,006 more customers than in 1951.

Portuguese Hydro-Electric Expansion

THE phenomenal expansion in the development of the hydro-electric resources of Portugal is well shown by the electrical statistics for 1951 just published by the Portuguese Ministry of Economics. From 1927 to 1950 hydro-electric capacity progressed by fairly even stages from 33 to 153 MW, representing an average increment of roughly 15 per cent. per annum, but from 1950 to 1951 the installed capacity rose from 153 to 362 MW, an increase of nearly 130 per cent. for the one year. For this remarkable increase the Castello do Bode and Vila Nova developments are, of course, mainly responsible.

This increase is reflected in the figures of electricity production. As compared with 1950, production in hydro-electric stations for public supply increased by 92·52 per cent. whereas that from thermal stations decreased by 58·86 per cent. If private generation be included, hydro-electric plants show an increase of 86·11 per cent. and thermal stations a decrease of 54·34 per cent., giving an overall increase of 10·81 per cent. The hours of utilisation during 1951 totalled 2,245 for hydro-electric plants and 1,196 for thermal plants. These figures show very clearly the way in which the country's hydro-electric capacity has been used to conserve fuel resources, for although electricity production shows a healthy increase the significant factor is the swing over from thermal to hydro-electric generation.

Shawinigan Expansion

THREE additional generating units—one each at the Rapide Blanc, Trenche, and La Tuque stations—will be installed to increase the total installed hydro-electric capacity by about 150,000 h.p., it was announced at a recent meeting of the Shawinigan Water and Power Company, by J. A. Fuller, the president. He estimated the Shawinigan company's capital expenditures at $38,500,000 for projects already planned between now and the end of 1955. The La Tuque development, it will be recalled, is the property of the St. Maurice Power Corporation, which is owned jointly by Shawinigan and the Brown Corporation, though the power station is operated as an integral part of the Shawinigan system. When the Rapide Blanc, Trenche and La Tuque generating stations were built—they were completed in 1934, 1951 and 1940 respectively—provision was made for the eventual installation of a sixth unit in each. While the three new units will not provide firm power to the full extent of their installed capacity they will be very useful at times of highest demand on our system. The additions will give Rapide Blanc an installed capacity of 240,000 h.p., Trenche 390,000 and La Tuque 267,000. Grand'Mère, Shawinigan Falls and La Gabelle have a total of 788,000 h.p. Four other Shawinigan sites, not yet developed, on the upper St. Maurice, have a total estimated capacity of about 700,000 h.p.

Stocking Reservoirs with Fish

THE North of Scotland Hydro-Electric Board, ever mindful of riparian interests, have released the first consigment of 5,000 yearlings and 2,500 two-year-old fish with which Loch Faskally is to be stocked. This is only one phase of the Board's extensive programme of stocking the many waters brought into being by the damming of Scottish rivers to provide electrical power. The reservoir of the Cowal scheme at Glen Tarsan has been stocked with the first of 2,585 yearlings and 5,860 fry; and similar numbers have been released into the reservoir of the Lussa scheme, in the Mull of Kintyre.

Last year the Board's stocking programme included the release of 6,300 yearlings into Loch Faskally; 2,500 yearlings and 6,000 fry into Glen Tarsan reservoir; 2,500 yearlings and 5,000 fry into Glen Lusc reservoir; and 1,000 yearlings and 500 two-year-old into the Storr Lochs reservoir in the Isle of Skye.

These activities suggest that the Board are determined to improve and extend amenities rather than merely maintain them, and we trust that they will be given credit for this endeavour at least by their more moderate-minded detractors.

Rochemaure-Montélimar Particulars

WE are now able to give some technical particulars of the Rochemaure-Montélimar scheme, the inauguration of the work on which by M. Mayer we reported last month. This scheme marks the commencement of a new stage in the harnessing of the most important river in France, and is another step towards the completion of the very large programme of the Compagnie Nationale du Rhône, which commenced in 1948 with the inauguration of Génissiat, and was followed last year by the commissioning of the outstanding hydro-electric and navigational works at Donzère-Mondragon.

The new power station will be on the left bank of the river about 10 km. south of Montélimar, and will be sited on a canal system comprising 12 km. of intake canal and 2 km. of tailrace. This canal system, which will be navigable, will be 125 m. wide (somewhat wider than the Suez Canal), and will have a depth of 12 m. The water intake will be situated to the north-west of Montélimar and the dam will be several hundred metres above this point, near the village of Rochemaure.

The power station will operate under a gross head of 19 m. and will have an installed plant capacity of 240,000 kVA, made up of six 40,000 kVA units, producing a mean output of 1·6 milliards of kWh per annum.

Course in Fluid Power Controls. An advanced course in fluid power controls will be given from July 6 to 17 during the 1953 summer activities at the Massachusetts Institute of Technology. Further information may be obtained from the Director of the Summer Session, Room 3-107, Cambridge 39, Massachusetts.

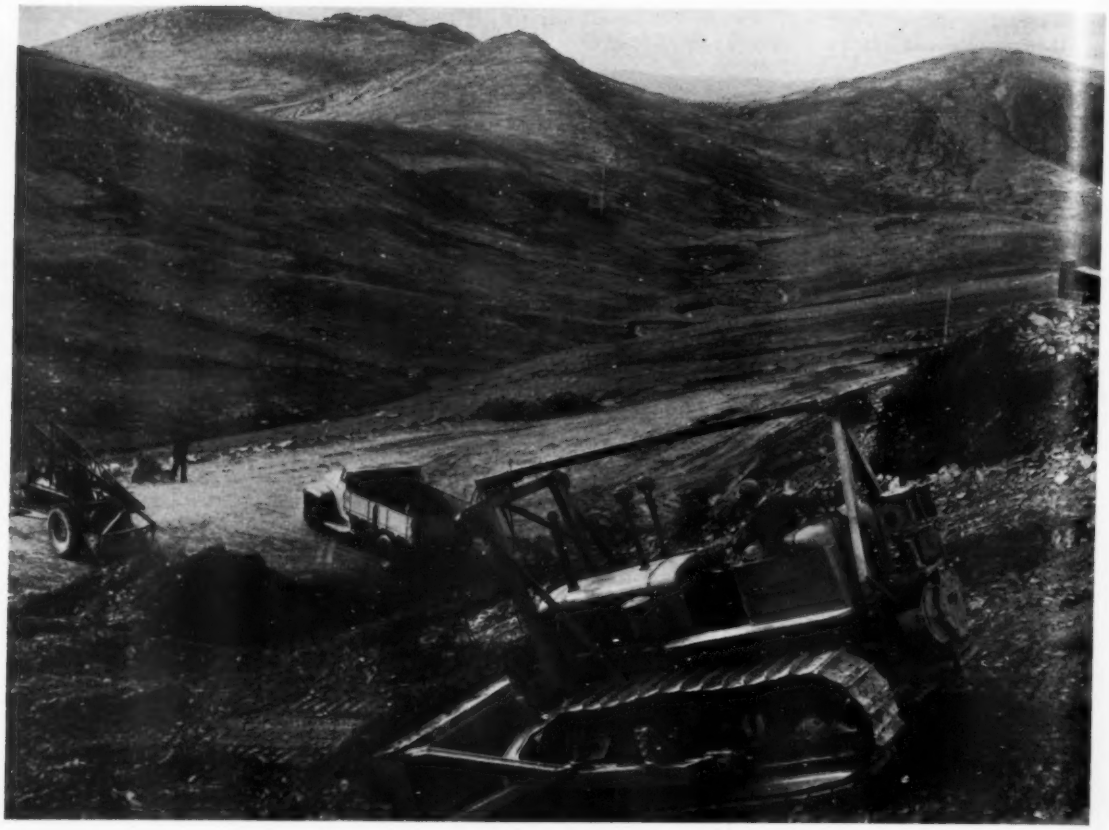


Fig. 23. Roadwork near the summit of Mt. Kosciusko

Snowy Mountains

In this final article we recount steps taken by the authority to implement the development, and describe the progress up to date.

PART THREE

THE foregoing analysis and outline of the project substantially follow the findings of the Technical Committee as set out in their Final Report,* although our description includes certain later modifications to the scheme and the most recently available figures. The Technical Committee's Report was intended only to provide preliminary information that was sufficiently reliable to enable the main features of the scheme to be determined. When the Snowy Mountains Hydro-Electric Authority was constituted one of its first tasks was to check, amplify and finalise this information so that it could be used as a basis for design. Naturally this work will take many years to complete, but by concentrating on certain vital areas the Authority is now able to go ahead with construction on the first stages of the scheme. The Authority has had for its objective the early production of power, and the early diversion of water to the Murrumbidgee. The upper reaches of the Snowy River were thought to be the most favourable for early power development, and contracts have been let for the Guthega dam and power station, which is scheduled to come into commission in 1954. To provide early irrigation water for the Murrumbidgee work has been concentrated on the diversion of the Eucumbene to the Tumut valley, and although this will take considerably longer than the Guthega project (probably 1958), investigation work has proceeded to the point at which it has been possible to invite tenders for station T1.

This achievement within three years of constitution is due largely to the immediate start that was made

* "Proposals to divert the Snowy River." Final Report by Commonwealth and State Officers. Obtainable from the Director-General, Department of Works and Housing, P.O. Box 2807 AA, Melbourne. Price 10s. post free (Australian currency).

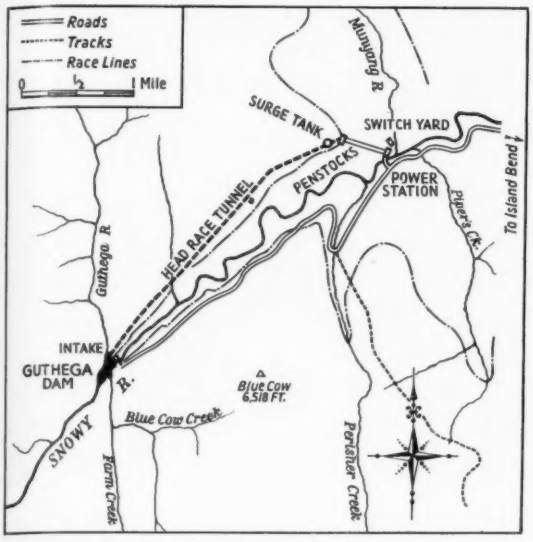


Fig. 24. Locality map of Guthega project

on preparatory works, particularly road and camp construction, which proceeded hand in hand with investigational work.

One of the major decisions in this field was to establish the permanent headquarters of the Authority at Cooma. This town is favourably situated on a railhead for the proposed working on the eastern side of the Great Dividing Range, and it is also a junction point of roads from Sydney and Canberra to the north, Eden to the east, Eastern Victoria to the south, and Kosciusko and Tumut to the west. A new township has been planned to the north of the existing town, and work is well advanced on its construction.

Plans for a works township at Jindabyne have been drawn up by a town-planning consultant. Temporary accommodation has already been erected and permanent construction is proceeding. This township will replace the present village, which will ultimately be submerged.

To serve the construction works on the Upper Snowy, a road has been built to Island Bend and

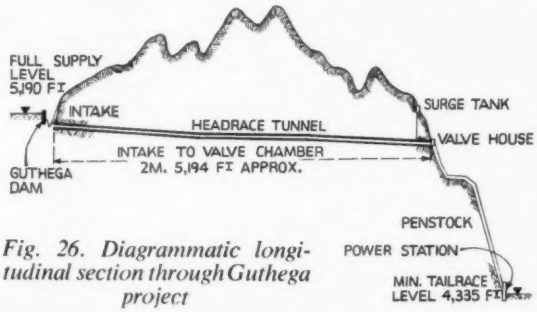


Fig. 26. Diagrammatic longitudinal section through Guthega project

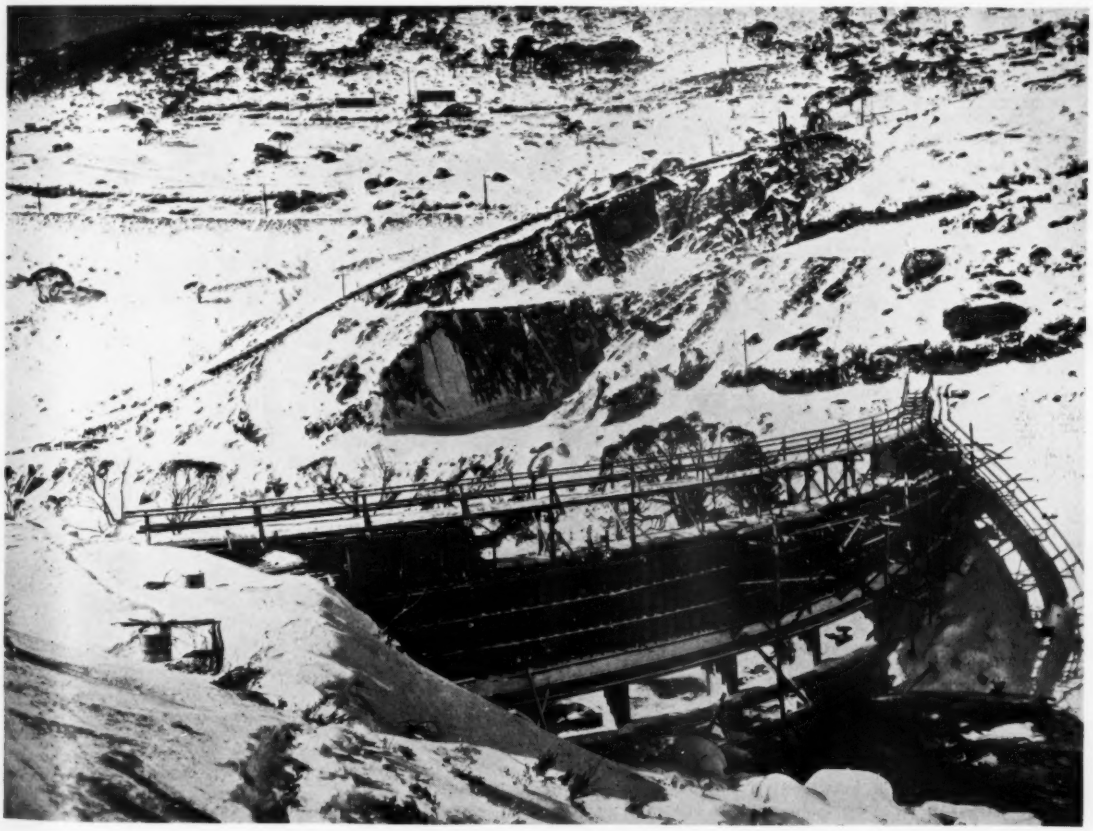


Fig. 25. A view of Guthega cofferdam under construction

thence up river towards Guthega, and a large camp established at Island Bend, with workshops, stores and diesel power plant.

In the Snowy-Tumut area, camps have been established at Adaminaby, Tumut Pond and Lob's Hole.

Diesel electric generating sets have been installed at various working points to provide power for construction. For the Guthega project, a diesel power station of 3,000 kVA has been built at Island Bend, and an 11 kV transmission line is under construction from Island Bend to Munyang and Guthega. The construction of the Adaminaby - Tumut Pond tunnel will require large amounts of power. A route for a 66 kV transmission line has been surveyed from Cooma via Adaminaby to Tumut Pond. This line will link with the 132 kV line from Canberra to Cooma, now under construction by the Electricity Commission of New South Wales.

Reliable communications are important in providing proper control of the Authority's activities at many scattered and isolated points. A frequency-modulated radio network is now in use linking Cooma with Jindabyne, Island Bend and Tumut Pond. Several motor vehicles, including two ambulances, have been equipped with wireless. High - frequency base radio stations have been built at regional centres to provide communications with survey and other mobile parties. Private telephone exchanges and services have been installed at Cooma and regional centres. A teleprinter service and additional direct radio circuits between Cooma and Island Bend are being installed.

Fig. 27. A view inside the Guthega diversion tunnel

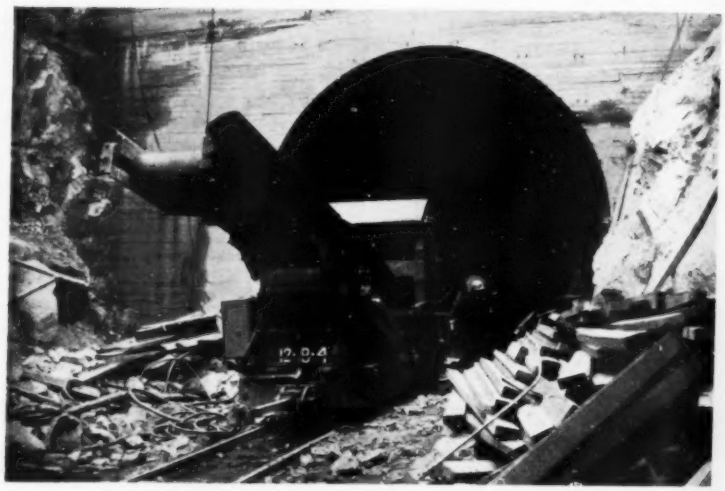


Fig. 28. Inlet portal of the Guthega-Munyang tunnel

Turning now to investigational work, surveying has presented many difficulties, due to the rugged nature of the terrain, to the immense amount of work to be done, and to the shortage of surveyors. Nevertheless, a large force of surveyors has been recruited, largely from overseas, and much work has been done, particularly on the Guthega and the Adaminaby-Tumut developments. Detailed ground surveys are being limited to the areas of the proposed works, but aerial photography is being used extensively in conjuction with ground surveys to produce maps of the terrain required for the investigation of alternative developments, the determination of approximate storage capacities, and the location of ancillary works. Work has also been proceeding on geodetic surveys, triangulation and precision levelling. A survey grid system has been established covering the whole of the area.

Geological investigations were hampered in the early stages by the shortage of competent diamond core drillers, but general geological mapping of the area has proceeded. Foundation conditions at various alternative sites for dams and associated structures have been investigated at Tumut Pond, Adaminaby, Island Bend, Guthega, Spencer's Creek and Jindabyne, and the geological conditions along the proposed alignments of the Guthega-Munyang and Adaminaby-Tumut tunnels examined in detail.

New stream-gauging stations have been established, bringing the total number now in use to 51.

One of the most pressing difficulties confronting the Authority has been the shortage of both professional staff and of labour. It was seen that this shortage could not be met by recruitment within Australia without depleting Australia's economy in other directions, and a policy has been followed of engaging personnel largely from overseas. Latest figures show a staff of approximately 1,000 officers and 2,000 wage employees. A similar difficulty obtains in respect of plant and materials, and contracts are being placed largely with overseas concerns.

Fig. 29. Outlet portal of the Guthega-Munyang tunnel

Guthega

As already stated in this article, and as announced at the time in WATER POWER, the designs for the Guthega project have been finalised, and the main contracts let. In accordance with the Authority's policy to execute its major works by contract, tenders for this project were advertised throughout the world in February, 1951, closing on May 21, 1951. Tenders were received from Britain, Norway, Germany, Italy and the United States of America.

To reduce the drain on Australian resources, the contract specification stipulated that the contractor must provide from overseas sources all of his own construction equipment, at least 90 per cent. of his staff and labour requirements, and all materials in short supply. However, to assist the contractor in making an early start on his work, steps were taken in advance of the letting of the contract to procure electric and diesel locomotives, compressors, tunnelling machinery and some plant for surface work. All of this equipment has since been made available to the contractor.

In July 1951 the tender of a Norwegian company, Ingenior F. Selmer A/s, was accepted for the Guthega project, and operations were commenced by the contractor in the spring of that year. A separate contract has been awarded to the English Electric Co. Ltd.

Fig. 30. Top section of Munyang penstock line looking towards outlet portal of Guthega-Munyang tunnel

Fig. 31. A general view of the power-station site and works at Munyang

for the manufacture, supply and delivery of two 30,000 kW turbo-generators valued at £500,000 which will be installed in the M1B power station.

The contract covers the design and construction of a concrete gravity-section dam 100 ft. high and 350 ft. long on the Snowy River immediately below its junction with the Guthega River; a pressure tunnel 3¼ miles long and approximately 19 ft. in diameter with an intake portal and control works at the upstream end; a surge tank at the downstream end of the tunnel to incorporate a raceline inlet, thus providing for the raceline to discharge directly into the surge tank; a conduit from the downstream end of the tunnel to the power station, complete with necessary fittings to serve the two main turbines, with provision for the future installation of a supply line to a third turbine; a power house to accommodate three 30,0000 kW Francis turbines; a tailrace and weir, and finally, access roads and bridges to provide access to the works when completed.

The following operational requirements were laid down:

(i) Spillway level at Guthega dam .. RL 5190
(ii) Minimum operational level in Guthega pondage .. .. RL 5155
(iii) Minimum tailwater level at power house (no discharge) .. .. .. RL 4335
(iv) Minimum tailwater level at power house with three turbines discharging a total of 1,750 cusecs .. .. .. RL 4341·5
(v) Normal maximum tailwater level at power house with three turbines discharging a total of 1,750 cusecs .. RL 4350
(vi) Maximum discharge through each turbine—for purposes of design of civil works (generating 30 MW per turbine) 583 cusecs

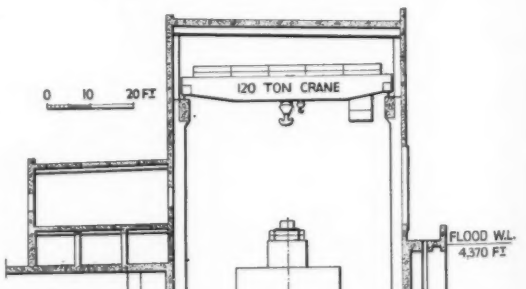


Fig. 32. Cross-section through Munyang power station

Fig. 33. Munyang power station under construction showing shuttering for draught tubes

(vii) Maximum head loss between Guthega pondage and the main valves at the turbines for simultaneous discharge through each turbine of 583 cusecs .. 72 ft.

The Guthega dam will have a spillway, without flood gates, capable of discharging a flood flow of 25,000 cusecs with appropriate freeboard on the remainder of the structure, and capable of discharging a flood flow of 50,000 cusecs without overtopping the dam. The reservoir outlets are to be capable of passing not less than 600 cusecs down the Snowy River with a water level in the reservoir at or below the sill of the tunnel portal. The spillway energy dissipator is to be capable of handling discharges of up to 50,000 cusecs and was the subject of model tests at the contractor's headquarters in Norway.

The surge tank will provide for the sudden and simultaneous rejection by the power house of full load of 90,000 kW and will be designed to receive a discharge from the raceline of 200 cusecs.

To avoid possible delays in the manufacture of the steel penstocks the Authority placed orders on the Continent for the supply of the steel plate required before the contract was awarded. This material is now coming to hand in sufficient quantities to enable a start to be made with the manufacture of the penstocks and a tender has now been accepted from a large pipe manufacturing organisation in New South Wales for the fabrication of the pipes. The contract provides for the work to be completed by September 1953.

Good progress has been maintained by the Guthega contractors, as will be seen from the accompanying photographs. Work on the upstream cofferdam is nearing completion and progress on the diversion tunnel, despite early checks due to unsound rock, has been satisfactory. Excavation for the dam itself has revealed rather disappointing foundation conditions and has necessitated additional work before designs can be prepared.

Naturally occurring deposits of concrete aggregate materials have also been disappointing and have necessitated a much more comprehensive trial mix programme than was anticipated. In this regard the Authority has been able to assist the contractor by making available laboratory facilities at Island Bend.

Agreement between the Commonwealth and the U.S.A.

An agreement entered into between the Commonwealth of Australia and the United States of America on November 16, 1951, provides in part that the Bureau of Reclamation of the United States Department of the Interior is to give technical training in the United States to selected Australian engineers and will give technical co-operation and assistance, as the Bureau's programme permits, in design and construction on various works relating to the scheme, as

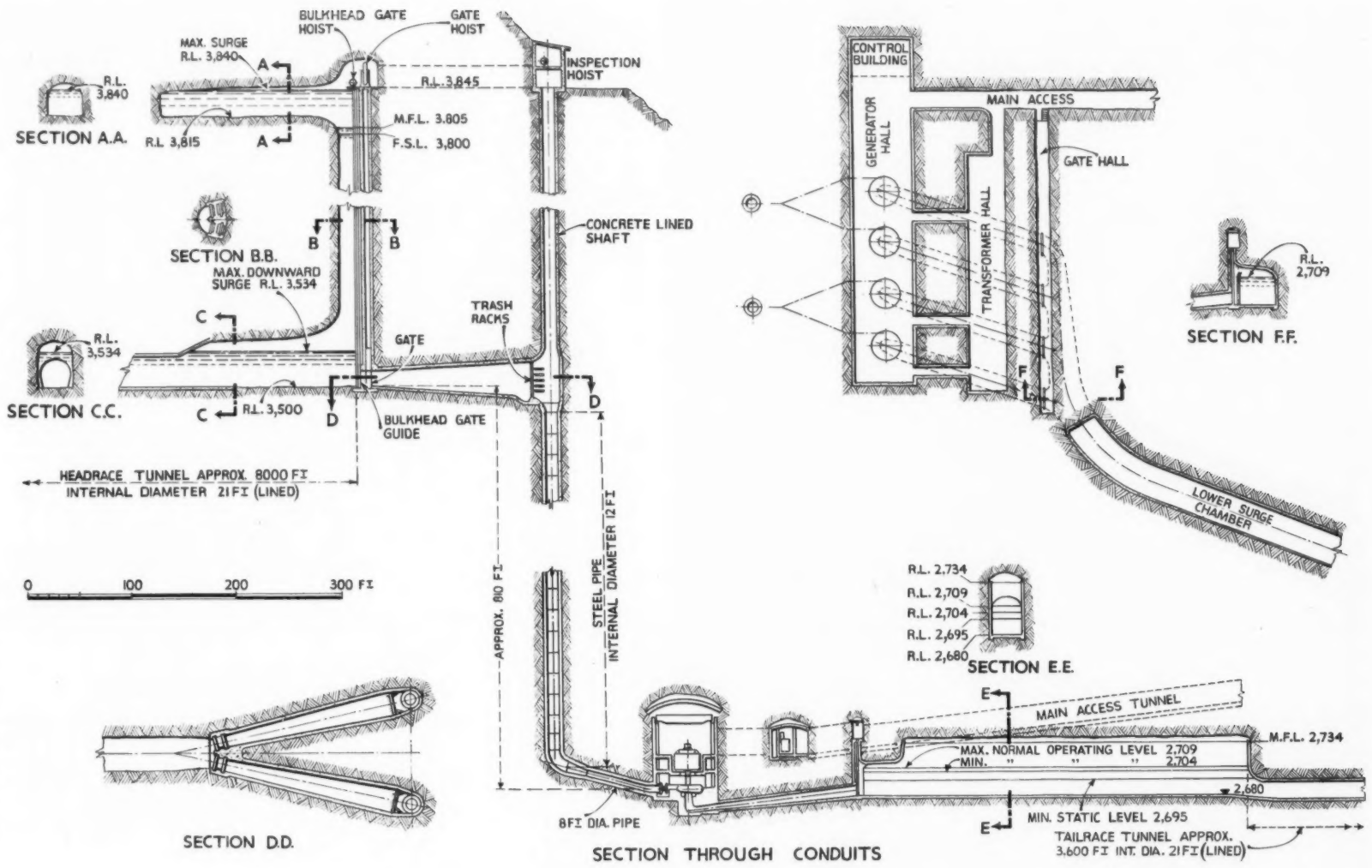


Fig. 34. Tentative layout of T1 power station from surge tank to tailrace tunnel

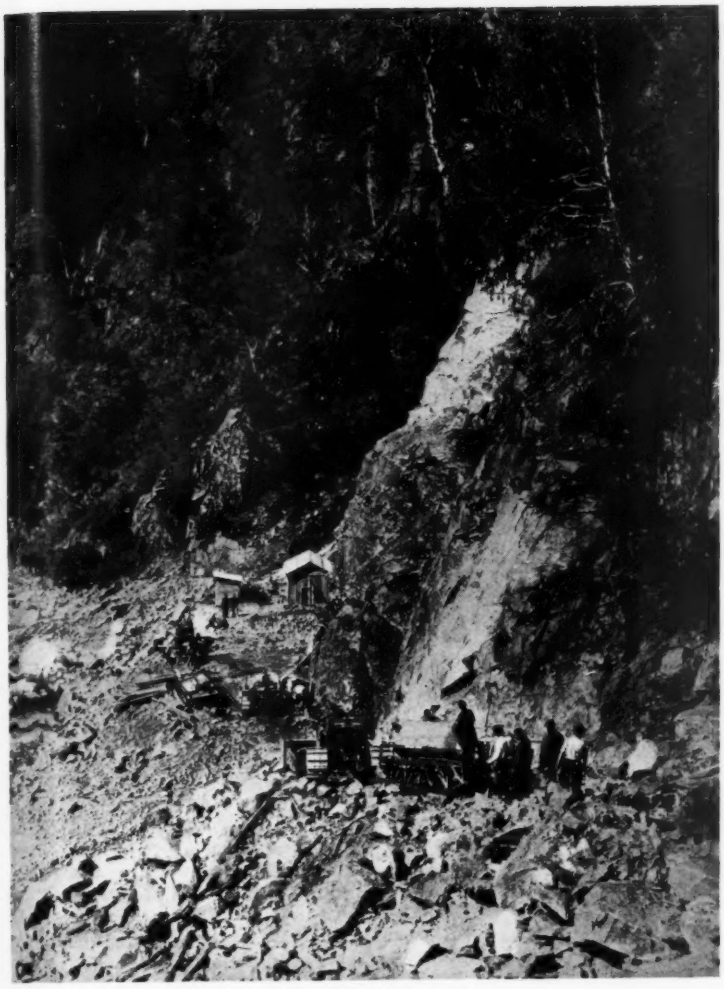


Fig. 35. Site of inspection adit for T1 power station

requested by the Commonwealth Government.

Pursuant to this agreement the Commonwealth requested that the Bureau of Reclamation prepare designs and technical portions of contract specifications for certain features of the Snowy Mountains Hydro-Electric Authority developments. The specific features involved in this request were: the Adaminaby-Tumut tunnel, with appurtenant shafts, intake and control works; the Tumut Pond dam, and the power tunnel from Tumut Pond to, and including, the surge tank.

Under this agreement, not only will the Authority gain the benefit of the extensive experience of the Bureau's great organisation, but also by handing over the design of a section of the work, the Authority's staff will be able to put in hand other work which otherwise could not have been undertaken at this stage.

Following the ratification of the above agreement, a Board of Bureau of Reclamation technical advisers visited Australia in February 1952 to discuss and review the Snowy Mountains programme and the Eucumbene-Tumut diversion proposals in particular.

The Bureau of Reclamation subsequently submitted a detailed report to the Authority containing the following recommendations, which were later adopted by the Authority as the basis for the preparation of detailed designs:

(a) The Adaminaby-Tumut Pond and T1 power tunnels are to be concrete lined throughout.
(b) A shaft, whose capacity is to be determined by the Authority at an early date from studies now in progress, is to be provided above the main tunnel at the junction of the Tumut River and Happy Jack's Creek for the intake of water.
(c) The Tumut Pond dam is to be designed as a concrete arch dam at the dam site furthest downstream of four sites investigated by the Authority.
(d) An unlined construction adit is to be provided at the Tumut Pond end of the main tunnel for access and to provide for muck disposal downstream of the dam.
(e) The Tooma diversion works are to be deferred for the time being.
(f) A major programme of investigation into the suitability of naturally occurring concrete aggregates is to be undertaken at high priority.

In anticipation of an early start on the northern diversion proposals, considerable developmental work had already been carried out by the Authority's construction forces. Not only were survey and geological investigations well advanced, but 50 diamond drill borings had already been put down to prove the suitability of the main tunnel line, and considerable effort had been devoted to opening up access into the Tumut valley where this has proved particularly difficult.

In addition, a regional centre has been established at Tumut Pond where barracks accommodation for over 300 staff and workmen has been provided. Office accommodation, plant workshops and stores buildings have also been erected.

The Authority has already commenced the driving of an exploratory tunnel to the site of the T1 underground power station. This tunnel will be approximately 1,000 ft. in length and will have a cross section of 8 ft. by 8 ft., its location being such that it will eventually become part of the wash tunnel from T1 station.

The early completion of the exploratory tunnel is considered essential in order to provide basic information which will enable designs of the T1 proposals to be completed on time.

Work is also proceeding at high priority on investigations into the suitability of the locally occurring concrete aggregates in this region. A concrete-research laboratory has been established at Cooma and samples

of the more suitable materials from the area stockpiled for laboratory experimentation. Crusher and trial mix experiments have already begun and promising results obtained.

Present plans provide for the installation and operation of the first generator in the T1 power station by June 1957 and for the third generator to be functioning by the following year. The first two generators will be put into operation before the completion of the Adaminaby-Tumut Pond Tunnel. The fourth and final generator for the T1 station should be operating by the end of 1958 and will be commissioned before the completion of the Adaminaby dam.

To obtain the maximum benefit from the Tumut River proposals therefore, the Blowering dam should be completed by 1958.

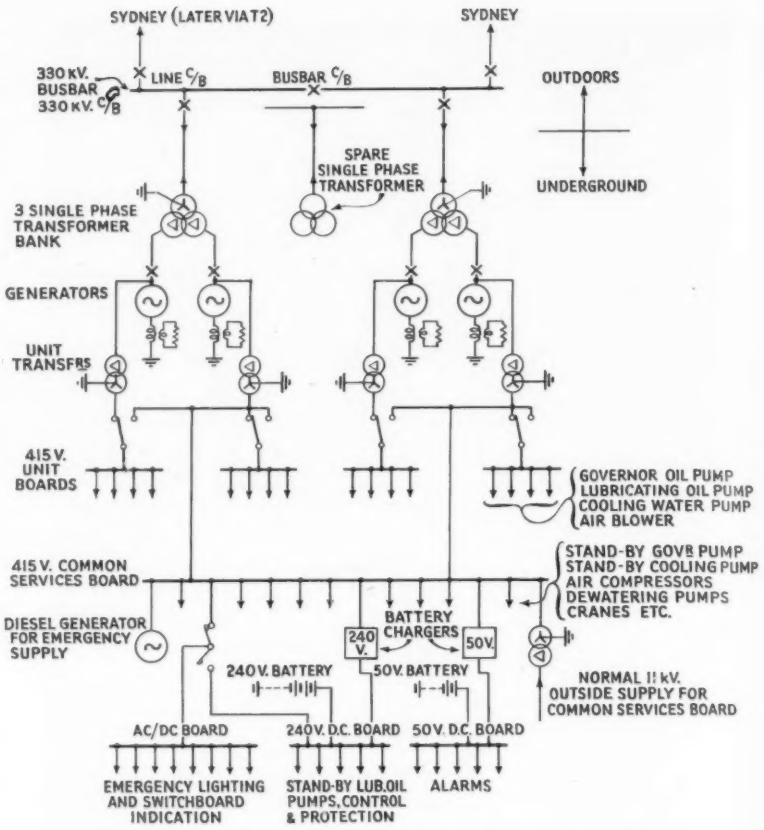


Fig. 36. Single-line electrical diagram of T1 power station

Electrical Transmission System

In view of the large power output of the ultimate scheme and the distance of about 250 miles to the main load centres, an investigation was conducted on the technical aspects and the economics of various transmission voltages covering the range from 220 to 380 kV. The current practice of other supply authorities in the field of extra-high-voltage transmission was analysed and the question of obtaining heavy equipment with the desired electrical characteristics was studied. Although the main purpose of the projected system is the bulk transmission of power from the Snowy Mountains Area to the capital cities in the adjoining States, it will also serve as a "backbone" to the 132 kV system in New South Wales.

These various considerations led to the decision to adopt a voltage of 330 kV. This voltage had recently been chosen by the American Gas and Electric Corporation, and a slightly higher voltage (345 kV) by the British Columbia Electric Corporation. Of existing systems, only that belonging to the Swedish State Power Board has a higher voltage (380 kV), but in the case of the Snowy Mountains Authority it was not possible to justify the higher voltage on economic grounds.

Acknowledgments

We are greatly indebted to the Snowy Mountains Hydro-Electric Authority for permission to publish this series of articles and for the many facilities they have afforded us in placing at our disposal technical reports and papers, drawings and photographs and in keeping us advised of current progress.

BEAMA Annual Report

The 42nd annual report of the British Electrical and Allied Manufacturers Association affords every evidence that the industry is on its toes to meet all demands for power-station equipment both at home and abroad. This is exemplified by the record installation of 1,540 MW of capacity by the British Electricity Authority during 1952 as compared with 1,235 MW in 1951; moreover, plant exported constituted a record achievement at 900 MW. In the considered opinion of the Council, there is an inescapable necessity, if Britain is to enjoy complete economic recovery, for the B.E.A. programme for new plant to progress from year to year from the present increment of 1,540 MW per annum to some figure approaching 2,000 MW.

Despite some falling off in certain products, the export achievements in 1952 were outstanding. Direct exports alone amounted to no less than £218 million, representing an increase of 15 per cent. on the 1951 figure. Much of this increase was due to an improvement of £10·5 million in electrical machinery exports and to the expansion of £8·5 million which took place in the shipment of cables and electric wiring.

At the present time no less than 73 per cent. of the hydro-electric plant on order is destined for overseas, principally the Dominions and Colonies, although Spain is receiving a substantial proportion.

Fig. 1. A view of the Athirapally Falls where 115 MW may be developed

The Chalakudy River Development

A broad outline of this scheme, which will ultimately make an important contribution to the power supply of India, is given by R. Dorai Rajan

THE Chalakudy River, which drains the western slopes of the Anamalai (elephant) hill, passes through the former Cochin State (part of the present Travancore-Cochin State) and bids fair to become one of the best utility rivers in India. In its upper reaches this river traverses thickly wooded forests which are intersected by narrow gorges containing falls and rapids which readily lend themselves to power development. It is estimated that the Chalakudy and its chief tributary, the Sholai Ar, have a

Fig. 2. The Chalakudy River flowing through one of the thickly wooded forests

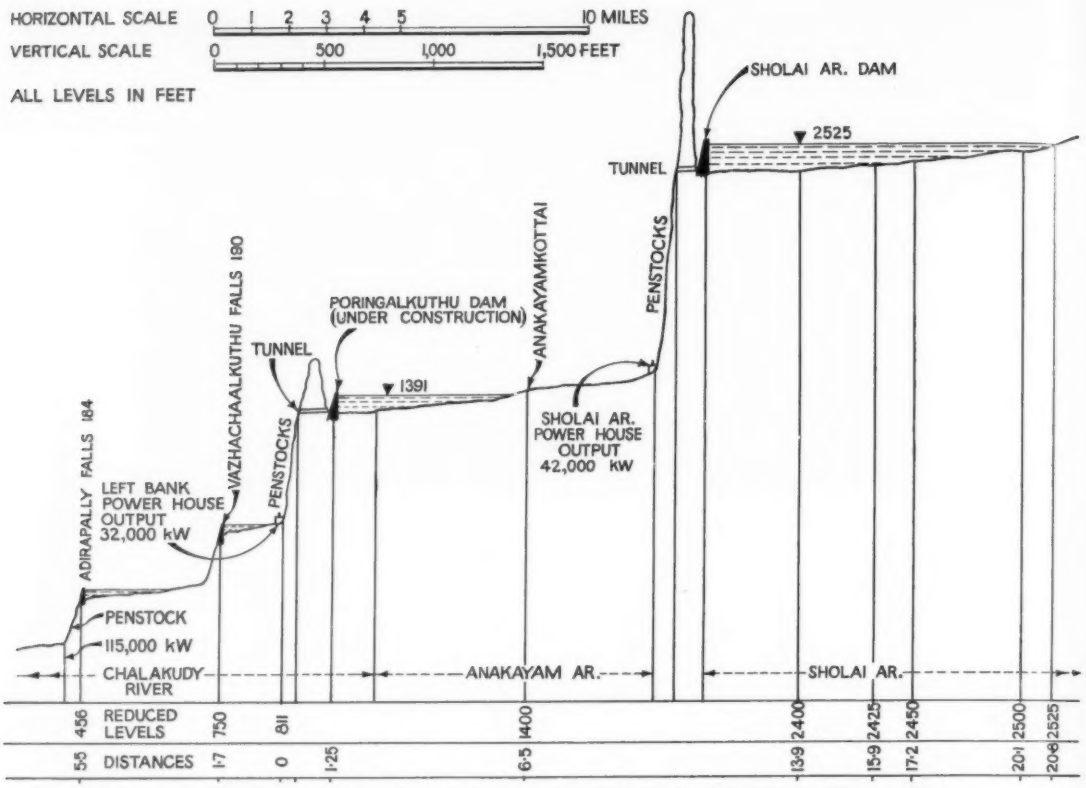


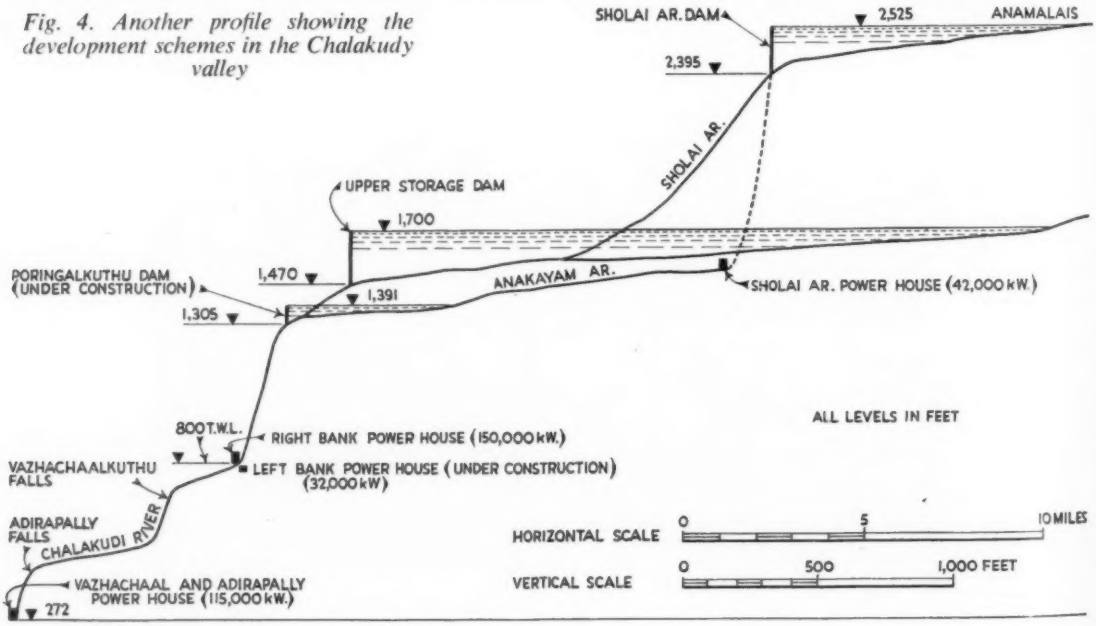
Fig. 3. A profile of the various developments proposed in the Chalakudy River valley

potential for power development of 350,000 kW.

The first stage of the Poringalkuthu site on the left bank of the Chalakudy River is now in course of construction; initially 24,000 kW of capacity will be installed but ultimately 48,000 kW will be developed.

The second stage, on the right bank of the river, contemplates the construction of a dam known as the Upper Dam, three miles above the present Poringalkuthu dam and just below the confluence of the Karapara and Sholai Ar Rivers, for a storage of 21,000

Fig. 4. Another profile showing the development schemes in the Chalakudy valley



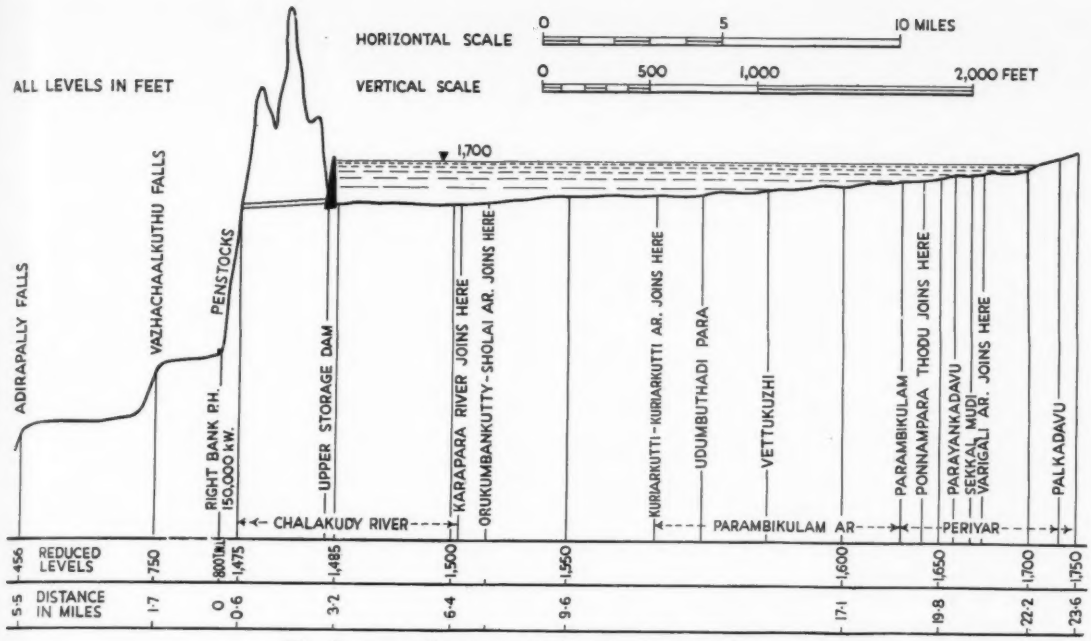


Fig. 5. A profile of the Poringalkuthu right-bank scheme

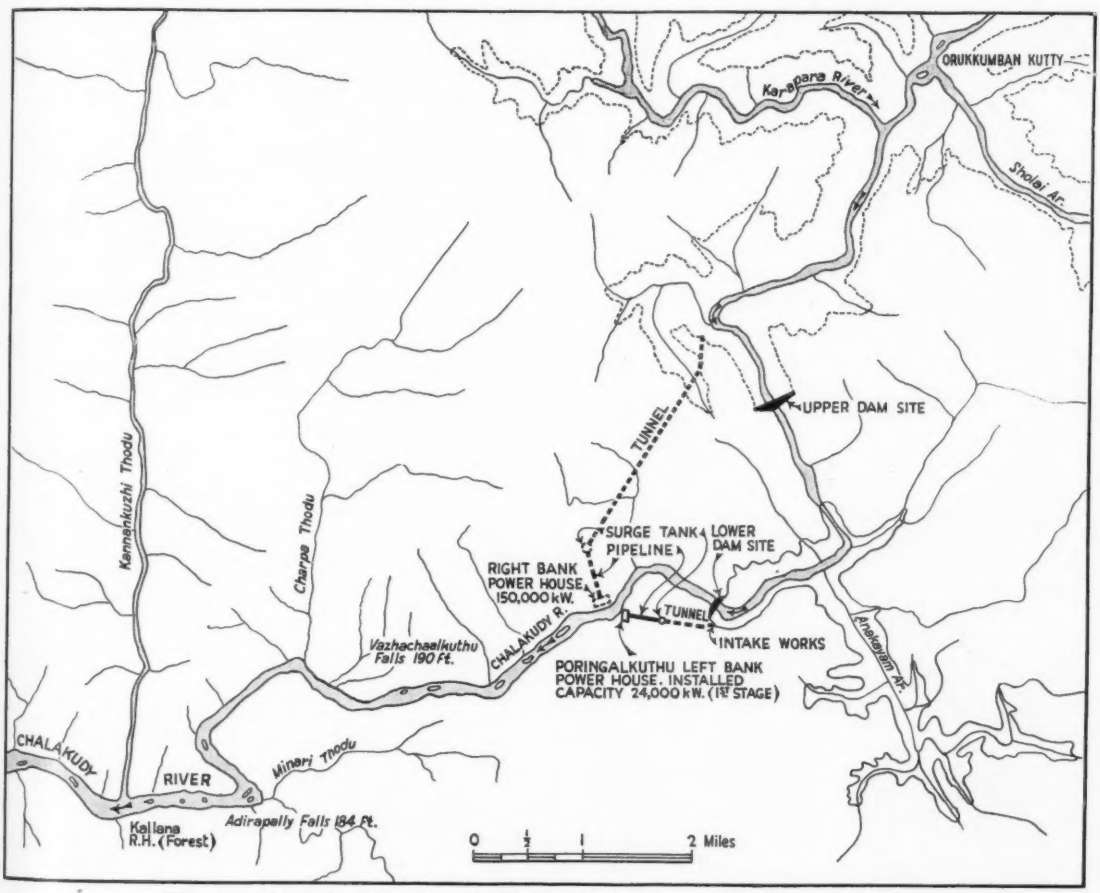


Fig. 6. A key plan showing the Poringalkuthu left- and right-bank schemes

million cu. ft. This reservoir will be capable of regulating the flow of the river to about 2,700 cusecs for development of power. A diversion tunnel some 11,000 ft. long will carry the flow through the intervening hill to pipelines 2,600 ft. long descending to the power house, 850 ft. below. The power station will contain five generating units capable of developing a total of 150,000 kW. at 60 per cent. load factor.

The catchment area of the river above the dam site is 349 sq. miles and is drained by five streams, all tributaries of the Chalakudy River. The average annual rainfall over this area is 150 in. and the average run-off 87,000 million cu. ft. during 1950-51 and 1951-52.

The Upper Dam, which is estimated to cost Rs. 320 lakhs, will be 1,500 ft. long and will have a height of 230 ft. above river-bed level. This construction will involve the laying of 19 million cu. ft. of mass concrete, and to mix and handle this material two cableways and a batching plant will be installed. It is estimated that this work will be completed in about 1,000 working days, or about four years, at the rate of 700 cu. yards a day. The project can thus be completed in five years allowing one year for preliminaries. A maximum flood discharge of 75,000 cusecs will be taken care of by radial crest gates and two under-sluices costing Rs. 20 lakhs.

The maximum discharge through the 11,000 ft. tunnel, which is to cost Rs. 72 lakhs, including the intake works, is 2,700 cusecs, the velocity of the flow being 8 ft. per sec. The area of the finished section will be 337 sq. ft. It is expected that 95 per cent. of the tunnel will be cut in solid rock and lined with 8 in. of concrete.

Five penstocks, each 2,600 ft. long with a diameter of 7ft. and designed for 530 cusecs discharge, will feed the five machines. The total weight of the penstocks will be 8,700 tons costing Rs. 238 lakhs, this including the control equipment.

The surge shaft will be 225 ft. high and will be cut in solid rock, the lowermost 55 ft. having a diameter of 80 ft. and the remainder a diameter of 25 ft. The estimated cost is Rs. 12 lakhs.

The power house, which will be of reinforced-concrete construction, costing Rs. 30 lakhs including the travelling crane, which will be 350 ft. long and 85 ft. wide and will accommodate five generators, each developing 30,000 kW. The turbines, generators, switchgear and transformers will cost Rs. 300 lakhs.

At another site above this dam on the Sholai Ar, it is proposed to utilise a head of 1,000 ft. in conjunction with a storage capacity of 4,800 million cu. ft., impounded by a 160 ft. high dam. A tunnel will be necessary, 5,000 ft. long, to bring the water to the power station which will be designed to generate 42,000 kW. The tailwater will join the Anakayam Ar, also a tributary of the Chalakudy River, about 14 miles above the Poringalkuthu site and join the main river above the Poringalkuthu Upper Dam about five miles upstream of the dam now under construction for the first stage of the Poringalkuthu left-bank scheme.

Two other sites lower down Poringalkuthu at the Vazachadl and Athirapally falls, where a total drop of 600 ft. is available, are also proposed for development and are estimated to be capable of accommodating 115,000 kW capacity.

Thus, there will finally be five generating stations on the Chalakudy River, utilising the same water, while a total area of 99,000 acres will be irrigated.

The scheme has been designed by Mr. George Oommen, chief construction engineer for hydro-electric projects in the Travancore-Cochin State.

Book Reviews

"Aménagements Hydro-Electriques" (Hydro-electric Developments). By I. Leviant, Ingénieur des Ponts et Chaussées, foreword by H. Varlett, Director of Gas and Electricity at the French Ministry of Industry and Commerce; published by Dunod, 92, rue Bonaparte, Paris 6. 8 in. by 5½ in., VIII-148 pp., 18 ff., 2nd Edition 1951. Price in France, paper bound, Fr.640.00.

This work is a synopsis of the most characteristic and latest features of French hydro-electric developments, with emphasis given to the evolutionary phases.

The first part is devoted to the new doctrines now prevailing in hydro-electricity: a single fall is no longer regarded as an independent source of energy, and has become a link in an organised system; in other words general interest has taken the place of determined particular interests. Since the advent of rational interconnection, tactical considerations are receding, and a real strategy must come into play in hydro-electricity. After a broad survey of the expansion of water power in France, and of the present position and future possibilities, the various kinds of consumption and production are reviewed in chapter II, and the adaptation problems (fluctuations in the extent of consumption and of power supply available, hydraulic regimes) are discussed in chapter III. Interconnection is then reviewed in its various aspects: the part it plays in adaptation, its other advantages, expansion, implementing, operating systems and international exchanges.

Interconnection alone is however unable to solve the adaptation problems intervening between supply and demand and must be supported by adequate storage reservoirs, which offer the possibility of energy transfers from one period to another. Chapter V covers in a condensed but exhaustive form the operation of storage reservoirs—modes of accumulation, secondary duties (flood control), importance of reservoirs, their influence on downstream installations, etc.

Thermal energy, without which adaptation could not be fully carried into effect, is briefly reviewed in chapter VI which concludes the first part of the book.

In the second part, the author approaches the guiding principle of modern hydro-electric development. After a brief survey of the evolution of hydro-electric developments, chapter II deals with the reservoirs and the conditions intervening in their construction—topographic, geological, hydrological, industrial and collective. By collective conditions, the author means those conditions that proceed from the existence of inhabited places, roads and railways, bridges, farmland, beauty spots, etc. Chapter III covers catchment areas, choice of valleys, impounding, and pumping. The various types of power houses are reviewed in chapter IV. General considerations

are set forth in chapter V, and followed by an extensive bibliography divided into seven sections:—hydraulics and works of a general character, expansion of electricity in France, hydrology, interconnection, thermal energy, reservoirs, operation of powerhouses.

Though applying primarily to conditions obtaining in France, this highly interesting synthesis will prove very useful to all who take an interest in the harnessing of water to power generation from either the financial or technical aspect. In elaborating this second edition of his work, the author has revised and enlarged its contents and taken into account all the changes which have occurred in matter of electricity since the publication of the first edition in 1943. The printing and graphs are excellent.

Importance of Inlet Design on Culvert Capacity. Technical Paper No. 13, Series B. By L. G. Straub, A. G. Anderson and C. E. Bowers. Issued by the University of Minnesota, St. Antony Falls Hydraulic Laboratory, Hennepin Island, Minneapolis 14, Minnesota, U.S.A. January 1953.

This paper considers simple culverts used in roadway construction and thus has a very limited application to hydro-electric schemes *per se*. It does, however, offer some very useful information on a number of deficiencies exhibited by inlet designs, which have often proved to be the limiting factor in the capacity of culverts.

The extensive series of experiments described deal with culverts having free outlets, culverts with free outlets on steep slopes, culverts on the horizontal or on mild slopes, and short culverts. In general, the objective of the investigation was to determine the design of a structure which, under the conditions imposed, would discharge a given flow with the minimum head; that is, the most economical culvert—normally the one having the least cross-sectional area.

Les Barrages en Terre Compactée, Pratiques Américaines (Earth Dams, American Practice). By G. Post and P. Londe. Preface by A. Coyne. Published by Gunther-Villars, 55 Quai des Grands-Augustins, Paris 6. 185 pp. 64 ff. Price 2.350 fr. (postage 110 fr.).

In a preface to this book, Monsieur A. Coyne remarks that although there are very few earth dams in France, some are being considered now and more will come in the future, as the technique evolves. He therefore found himself bound to send two of his engineers to the U.S.A. to get first-hand information on the American technique on earth dams. The book under review summarises their report in 185 pages (64 figures and diagrams).

The first part of the book is an elementary treatise on soil mechanics generally, but there the emphasis is on those aspects which are essential for earth dam design and construction (resistance-moisture relation, compactness, shearing, permeability, classification of the soils).

The second chapter deals with the design of earth dams—types of dams, overflow structures, infiltration and stability. Concerning the stability, the emphasis is on the Swedish method of Fellenius, with some amplification. Great importance is attached to the pore pressure in the soil and its detrimental effects, but the method of Brahtz has not been dealt with.

The third part of the book deals with dam foundations (stability, settling, shearing, imperviousness).

The final part (pages 149-180) deals with the organisation of the site, the transport of material, the methods of compaction and the treatment of foundations. A special chapter deals with the methods of observation and measurement of dams. Practical examples are given both for the design of dams and the organisation of the site.

Some of the material of the book under review seems to have been inspired by the recent (and difficult to obtain) publication of the Bureau of Reclamation on Earth Dams (Treatise on Dams). This makes the excellent book of Post and Londe even more valuable. It is also a very useful supplement to the book of Ch. Mallet, "Les Barrages en Terre," recently published, on the same subject, and comparison of the two publications is very interesting.

Talsperren Dams. Göschen Collection, No. 1044, published by Walter de Gruyter & Co., 13, Genthiner Strasse, Berlin, W.35, 6 in. by 4 in., 120 pp., 69 ff. Price in Germany, paper bound, DM.2.40.

Those of us who stayed in Germany in pre-war years to learn the language will remember the Göschen Collection, those popular little books which covered practically every branch of scientific and intellectual knowledge. The original publishers are gone and, in these days of austerity, so is the neat gold-yellow cloth-binding, so familiar in old days. But judging by "Talsperren," the present publishers appear to have succeeded excellently well in keeping the old tradition alive. The author of this new addition to the collection is no less an authority than Dr. Ing. F. Tölke, the eminent dam expert, Professor at the Technical High School in Stuttgart, who worked out the project for the N.S. de Monforte dam in Portugal.

After an initial chapter on generalities, geological and geotechnical preparatory investigations, foundations, subsoil water-proofing, choice of cements, and sulphated blast-furnace cement are reviewed and discussed. Chapters 7 and 8 are devoted to concrete techniques—fresh-concrete compacting and vibrated coarse-aggregate concrete, respectively. Incidentally chapter 8 gives an interesting account of modern German compaction practice and equipment (Keller's giant vibrators). Dam design is then covered in separate chapters, concrete, rockfill and earthfill dams being considered, while further chapters deal with model tests and measurements, and with the raising and reinforcing of existing structures. Flood control is discussed in chapter 14, which is divided into four sections—flood diversion during dam construction, overfall-type spillways, spillways not incorporated in the body of the dam proper (side channels, tunnels, bell-mouth weirs, etc.), and stilling pools. A rather short chapter on intake and emptying works concludes the book.

"Talsperren" is kept to practical rather than on theoretical considerations, and there are but a small number of equations and graphs; it gives in condensed form an exhaustive and up-to-date survey of dam practice in a clear and fluent style which will hardly present any insuperable difficulty to the English reader with a fair command of German. The print is excellent, and the illustrations, both line and photographic, are very good.

Some Modern Methods of Site Survey

A description is given of some interesting survey work which was done for the Errochty hydro-electric project, and is mainly devoted to the accurate triangulation of Errochty dam. The remaining part of the article deals with aspects of other survey methods which may not be generally known.

By E. T. HAWS, M.A., A.M.I.C.E.

PART ONE

ERROCHTY dam is of the diamond-headed buttress type and is 130 ft. high. Its main length is composed of 28 buttress units spaced at 40 ft. centres. The axis of the dam is on a circular curve of 3,000 ft. nominal radius, and the angle between any two adjacent buttress axes is 46′ (Fig. 1).

Great accuracy in setting out had to be maintained during construction to achieve a uniform finish, and also for a more imperative reason. A 6 in. bitumen core forming part of the waterstop between adjacent buttresses will be continuous from near the bottom of the cut-off trench to road level. To melt bitumen into this core a steam pipe centred by cages is to be lowered the depth of the dam on completion of concreting. As clearance between the cages and the sides of the hole is small, the hole must be constructed in a true line. It was therefore decided at the beginning of the contract to establish triangulation stations accurate to $\frac{1}{8}$ in.

Reconnaissance

The provision for a possible direct check on to the dam itself introduced an extra condition in siting stations. The lift joints in the dam are to be horizontal in the head, then rising at 1 : 4 towards the downstream end of the buttress. Thus in order to see

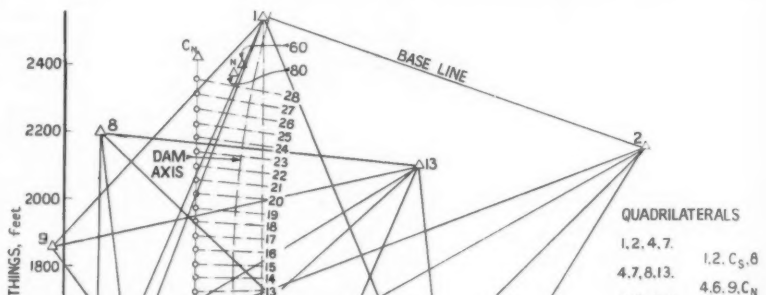


Fig. 1. Errochty dam triangulation

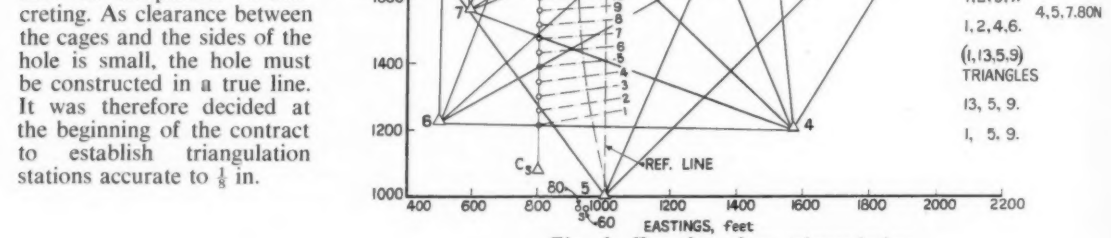


Fig. 2. Limiting envelope for direct sight on to axis of dam

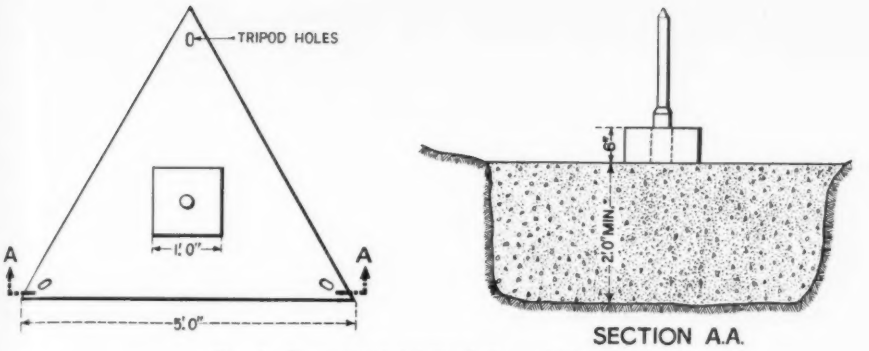


Fig. 3. Permanent triangulation station

directly on to the intersection of the buttress axes, the check station had to be upstream of the dam. About 600 ft. is the maximum length of sight desirable for these checks. It is intended to use a quadrant glass target set up on a tripod about 5 ft. above the intersection of buttress axes, and thus the worst condition for direct sighting will be as shown on Fig. 2 when concreting reaches level +1020. A limiting envelope of lines of sight just passing through the upstream edge of the buttress can be plotted as on Fig. 2 and any station plotted on this graph will be satisfactory if it lies above this envelope.

The contractor was given pegs at stations 1 and 5 as a reference line which forms a chord of the circular arc dam axis. The axis of buttress 14 is the perpendicular bisector of this chord, 758 ft. from station 5. Thus stations 1 and 5 had to be maintained as permanent points.

Intervisibility between stations was to be such as to allow intersection of the base of all sighting rods. In order to obtain a redundant fix for each station, braced quadrilaterals were devised. A rule that no angle should be less than 30° was waived later in view of all the other conditions, and in the final triangulation 5 angles were between 22° and 30°.

The only suitable site for a baseline was alongside and across the tarmac access road.

The four check stations 6, 7, 8 and 9 upstream of the dam were next sited. Long-range tacheometric shots were taken to see that the level and distance from dam axis suited the conditions shown in Fig. 2. Stations 4 and 13 completed the necessary quadrilaterals.

Because of its low position station 9 could only be fixed by two triangles, or later by a quadrilateral with two computed angles.

Preliminary Work

Nailed pegs were driven in at all the station sites and a preliminary triangulation made on them. The baseline was measured in approximately 90 ft. legs, between nails in pegs or the tarmac on line. Corrections were made for temperature, tension, and level.

The theodolite used for angular measurements was a Cooke, Troughton & Sims T.63 type optical-scale theodolite, direct reading to 20″. Two rounds on two faces were taken at each station, and stations were fixed by triangles only.

Construction of Permanent Stations

Fig. 3 shows the method of constructing a permanent concrete triangulation station. The target rod had to be suitable for accurate intersection at ranges between 600 and 2,000 ft. The steel rod chosen is shown in Fig. 4. This was suitable for intersection with a single hair at ranges of 1,000 ft. or more, and a nail was fixed in the centring hole for very short sights. The sighting rod has an internally tapped shank at its base, which screws on to a $\frac{1}{2}$ in. diameter stud grouted in the station upstand. The stud has a truly central machine-drilled $\frac{1}{16}$ in. diameter hole for centring the theodolite, and the shank of the sighting rod is machined so that the rod itself is truly plumb over the stud centre.

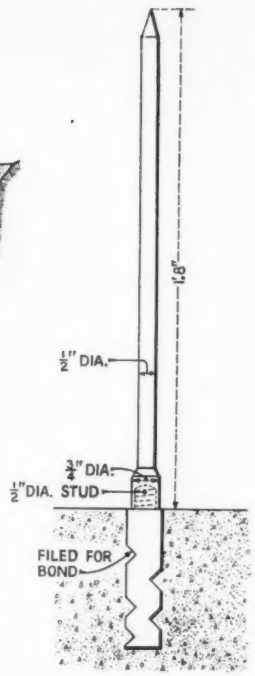


Fig. 4. Target rod

The colour scheme finally chosen was matt yellow for the sighting rods constructed against matt red screens. This has been entirely satisfactory, being easy to find, easy to intersect accurately, and not dazzling or tiring to the eye.

Accurate Baseline Measurement

At the altitude of the baseline, +1,000 ft. O.D., the weather is very seldom calm enough to allow any attempt at catenary banding. The band was therefore supported at 6 ft. intervals. The error due to sag in a 6 ft. span, with the band weighing 0·262 oz. per ft. and a tension of 10 lb. applied, is of the order of 2×10^{-5} ft. Thus the accuracy of reading the band ($\pm 1 \times 10^{-3}$ ft.) is far below that of the accumulative sag error on a 100 ft. leg.

A large peg was driven in very firmly on the baseline every 90 to 95 ft. The peg was cut off, about 1 ft. above ground level, so that no part of it would interfere with a band stretched on grade between it and the next peg in either direction. Just before the baseline was to be measured, flat-headed felt tacks were driven in flush with the surface of the peg and on line. Finally a pop mark on line was made on each felt tack.

For ends of legs on the roadway, iron dogs were concreted into the road metal, raised about $\frac{1}{4}$ in. above the surface. All lining in was done with the T.63 theodolite.

No means of supporting the band thermometer would accurately record the band temperature on a

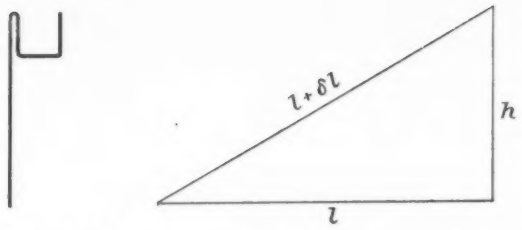


Fig. 5. Steel band support

Fig. 6. Level correction

sunny day, so both runs on the baseline measurement were made in overcast weather.

The band was supported on grade between pegs by steel bars bent into the shape shown in Fig. 5, by adjustable wooden slats made like easels and by wooden wedges. A further steel bar was driven in on grade behind the peg at each end, to take the strain off the peg when the tension was applied. The band was anchored at one end, lined in between pop marks, and tensioned. At a given signal, engineers at each end simultaneously read the band, and then the temperature was read. The band was then moved along a foot or two and readings repeated. Differences of the two sets of readings were compared, and if these differed by more than 0·001 ft. a further reading was taken. This was very seldom necessary.

A line of levels was run both ways along the nailed pegs for level correction (Fig. 6).

In this case, the maximum value of dl ($dl = h^2/2l - dl^2/2l$), ignoring the $dl^2/2l$ term, was 0·3 ft., giving a value of 0·00056 ft. for $dl^2/2l$. In only one other leg did the $dl^2/2l$ term have to be considered.

The reduced values of the two runs by the resident engineer's staff on the 1,217 ft. baseline had a range of 0·003 ft. The contractor's range was 0·025 ft. but the difference between means of the resident engineer's and contractor's runs was only 0·004 ft.

Preliminaries to Final Triangulation

A third-order triangulation with the T.63 on the permanent stations was carried out for interim checking. The agreed value of the baseline was used. A week was spent by the two observers familiarising themselves with the Cooke, Troughton & Sims "Tavistock" theodolite. Not only was necessary practice gained in speedy and accurate splitting of the light gap and in learning the positions of tangent screws, etc., but also a working technique was established. Metal folding legs were found to be unsatisfactory, in that changes in temperature caused differential expansion, thus throwing the instrument off level. A wooden tripod was substituted.

The trial observations were being made in May, and as shimmer was found to interfere with bisections of stations between 9 a.m. and 6 p.m., all observations were made either before or after these hours. Similar interference came from plant exhausts. In one case a bad closure was obtained in a trial triangle in spite of all the conditions being apparently suitable. It was discovered that the exhaust of a diesel-engined generator was discharging close to the baseline, though no shimmer was apparent on the sight. This had bent the ray by 5″, due to refraction at the boundary of the less-dense warmer air (Fig. 7). In consequence, it was decided that lines of sight across the works could be observed only when the contractor's plant was well away. A further undesirable effect, caused by bright sunlight, was unequal illumination of the light gap, which was found to be much easier to split when illuminated by the battery, and this means was used throughout the accurate observations. Furthermore, accurate observations with the instrument on its tripod were found to be impossible with anything stronger than a very light breeze, so the contractor provided a collapsible shelter.

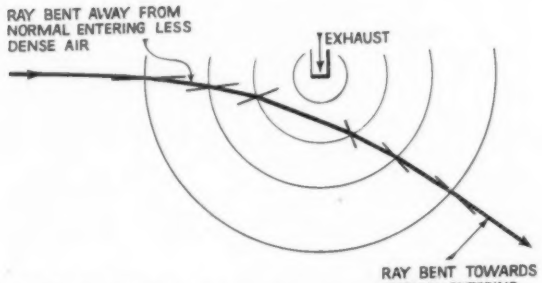


Fig. 7. Refraction by hot exhaust

Technique

During the trial runs the following technique for accurate observations was evolved.

(1) Check that all the required target rods and screens are securely in position, and no plant is in the vicinity of lines of sight. Erect shelter at station.

(2) Level the instrument approximately and then centre it over the station (a plumb bob shield was provided). Lock the tripod head.

(3) Level the instrument accurately.

(4) Sight each station and chose the most easily bisected as R.O. Try and find a landmark close to each station to be observed, to help to find it with the telescope while measuring, and to prevent overshooting. Check for optimum illumination of light gap.

(5) Clamp top plate to the bottom plate, with the scale reading approximately 0° and instrument face left.

(6) Intersect R.O. with bottom plate; clamp bottom plate.

(7) Release top plate and rotate two complete circles, swinging right. This takes up any strain in the bottom plate slow-motion system and removes the most frequent cause of bad closures back on the R.O.

(8) Approach R.O. carefully, swinging right. Elevate telescope till base of target rod is just on the single vertical cross hair side of the horizontal cross hair. Do not clamp vertical circle, as with a well-balanced instrument and careful handling the telescope will stay at the correct elevation. Focus on target rod. Clamp top plate only when those adjustments are made, to minimise chances of a slight knock spoiling results. Intersect and bisect target rod by tangent screw, moving swing right only. If the target is overshot, release top plate and swing complete circle to try again swing right. Be satisfied with nothing but a perfect bisection.

(9) Read horizontal scale. Mentally take the mean of

TABLE I. APPROXIMATE ADJUSTMENT OF QUADRILATERAL 1, 2, 4, 6

Angle	Observed value	1st Corr	2nd Corr.	Adjusted value	Log sin +	Log sin −	d	d^2	Side corr	Adjusted value	Check log sin +	Check log sin −
	° ′ ″	″	″	° ′ ″						° ′ ″		
a	48 04 36·7	−0·3	−1·1	48 04 35·3	9·871 5941 (6)		18·91	358	+0·3	48 04 35·6	9·871 5941 (11)	
b	43 40 07·5	−0·3	+0·7	43 40 07·9		9·839 1550 (20)	22·05	485	−0·4	43 40 07·5		9·839 1550 (11)
c	40 01 36·1	−0·2	+0·7	40 01 36·6	9·808 3083 (15)		25·07	630	+0·4	40 01 37·0	9·808 3083 (25)	
d	30 07 06·3	−0·3	+1·2	30 07 07·2		9·700 5235 (4)	36·29	1320	−0·6	30 07 06·6		9·700 5235 (−15)
e	66 11 07·5	−0·3	+1·1	66 11 08·3	9·961 3536 (3)		9·29	87	+0·2	66 11 08·5	9·961 3536 (5)	
f	54 50 33·1	−0·3	−0·7	54 50 32·1		9·912 5247 (1)	14·83	218	−0·2	54 50 31·9		9·912 5247 (−1)
g	28 51 13·4	−0·3	−0·7	28 51 12·4	9·683 5596 (15)		38·21	1460	+0·6	28 51 13·0	9·683 5596 (38)	
h	48 13 41·7	−0·3	−1·2	48 13 40·2		9·872 6218 (4)	18·81	354	−0·3	48 13 39·9		9·872 6218 (−2)
( )	360 00 02·3			360 00 00·0	39·324 8195	39·324 8279		$(d^2)=4912$		00·0	8235	8243

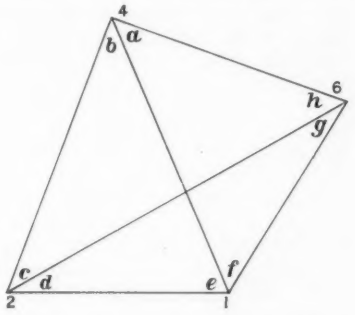
	° ′ ″
a+h=96	18 17·8
d+e=96	18 13·2
4)	4·6
	1·15

	° ′ ″
b+c=73	41 43·1
f+g=83	41 45·9
4)	2·8
	0·7

log sin +	39·324 8195
log sin −	8279
U_4	84

Note: Side corr $r_a=\frac{d_a}{(d^2)}\times U_4$ etc.

Finally a+h=15·5″ b+c=44·5″
d+e=15·1″ f+g=44·9″



four readings of the light gap, two approaching the fixed bar from each direction. With practice and an eye not overtired, these four readings will have a maximum range of 2″ to 3″. Call out mean to booker.

(10) Release top plate directly the reading is made and repeat (8) and (9) for next station and then each station back to the R.O. If the second reading on the R.O. differs from the first by more than 3″ the instrument has almost certainly been knocked, and readings for that face must be scrapped and repeated.

(11) Transit theodolite and intersect R.O. again face right, swing left. Repeat (9) and (10) on face right, swing left, the permissible closing error on the R.O. again being 3″. The booker can mean readings on two faces while the observer is making intersections, and should point out obvious errors immediately for a check reading.

(12) The other observer checks the levelling of the instrument and repeats (4) to (11) starting at approximately 45° on the R.O.

(13) The first observer repeats starting at 90°, and the second starting at 135°.

If the four reduced readings on any particular angle showed a range of more than 6″ the reading farthest from the mean was rejected and repeated. This was seldom necessary, and in fact only three angles showed a range of more than 5″.

All the outside observations were carried out in the early mornings and evenings of the last fortnight of May, 1950, when weather conditions were very favourable.

The "run" of the theodolite micrometer was tested, and an error of +1″ on the 20′ was discovered. This was ignored for computation, but its effect was considered for later statistical analysis. With the pointings actually used the average deviation of an observation of an angle due to micrometer-run error was +0·05″.

Adjustment and Computation of Results

In view of the number of redundancies of the observed figures and the consistency of the observations, the resident engineer's staff did not consider it necessary to apply a rigorous adjustment to the figures by means of forming the normal correlative equations, in order to reach the desired accuracy in co-ordinates. The contractor's staff did apply such a rigorous adjustment, and, after solving 16 simultaneous equations, agreed co-ordinates of all setting-out stations to within $\frac{1}{8}$ in.

The method employed was that of approximate adjustment of quadrilaterals for observations of equal weights, involving the theory of probability. Table I shows an adjustment table for one quadrilateral, the tabular form being as shown in Clark's "Higher Surveying." Several quadrilaterals have common angles and triangles, so the following procedure was adopted.

(1) Adjust all quadrilaterals by themselves.

(2) Adjust quadrilaterals 1, 2, 4, 7 ..... A
4, 7, 8, 13 ..... B
8, 13, 4, 6 C
and 1, 2, 5, 7 ..... .

mutually. This was done by giving angles common to two quadrilaterals the mean of the

values obtained in (1) and holding them fixed at that value during adjustment (2).

(3) Adjust quadrilateral 1, 2, 4, 6 in conjunction with quadrilateral 1, 2, 4, 7 only.

(4) Compute co-ordinates of station 6 via quadrilaterals A, B and C and via quadrilateral 1, 2, 4, 6, direct from the baseline. This gave an idea of the accuracy of the survey. The two positions were found to be only 0·016 ft. apart, which was entirely satisfactory.

(5) Adjust all quadrilaterals mutually. This had the effect of applying a station adjustment at station 4, *i.e.* the values of the angle 7, 4, 6 obtained by the difference between quadrilaterals 13, 4, 8, 6 and 13, 4, 8, 7 and quadrilaterals 1, 2, 4, 7 and 1, 2, 4, 6, were made equal.

(6) Adopt values of angles obtained in (5) for the final computation of station co-ordinates.

The maximum quadrilateral angular error obtained by adding observed values was 6″, and the mean for all quadrilaterals was 3·7″, taking no account of sign. Similarly the maximum error in the other two angle equations was 5·8″ and the average for all quadrilaterals was 2·4″.

The maximum difference between first adjusted values of angles common to two quads. was 3·4″ but in eight out of the ten cases, it was less than 0·5″, and the overall average was 0·9″.

Station 9 had to be treated alone. The two positions as fixed by triangles 13, 5, 9, and 1, 5, 9, were only 0·009 ft. apart. After all the remaining stations had been co-ordinated finally the angles of triangle 1, 13, 5 were computed and the quadrilateral 1,13, 5, 9 was adjusted with those angles held fixed. The co-ordinates of station 9 computed from this quadrilateral were accepted, and the position is 0·006 ft. from the two positions found by triangles.

For the setting-out stations the values of co-ordinates obtained by the contractor's and resident engineer's staffs were meaned and accepted at the nearest 0·01 ft. for all future work.

Later Work

It was desirable to establish permanent stations on each buttress axis, and a reference line 200 ft. upstream of the reference line 1—5 was chosen. The master stations C_X and C_S at either end of this were fixed by direct banding from 1 and 5 and by braced quadrilaterals. The two values for distances to C_X and C_S computed from triangulation and from direct banding differed by only 0·007 ft. and 0·005 ft. respectively.

The stations on this reference line and on the buttress axes are of the pillar type (Fig. 9) and are shown by circles in Fig. 1.

The studs at 9 in. centres take bracket feet fitted to a Cooke, Troughton & Sims V120 type centring device, or a red channel-iron screen. The screen has an adjustable bracket to hold a knitting-needle target rod over the pop mark. The pop marks have been sited by bearings from triangulation stations.

The pillar stations 60 N & S and 80 N & S mark offset lines parallel to the main reference line, for establishing chainages on buttress heads. The N stations were triangulated and the S stations banded. The computed distance 60 N — 80 N differed by only 0·004 ft. from a check banding.

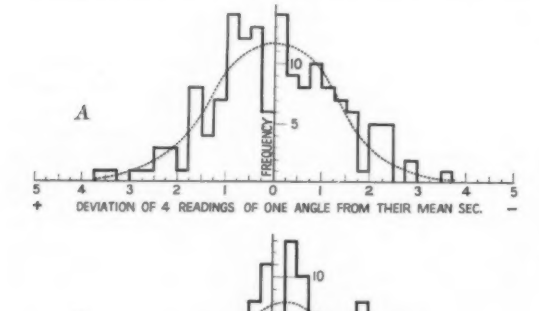

A
10
5
FREQUENCY
5 4 3 2 1 0 1 2 3 4 5
+ DEVIATION OF 4 READINGS OF ONE ANGLE FROM THEIR MEAN SEC. −
B
10
5
FREQUENCY
5 4 3 2 1 0 1 2 3 4 5
+ DEVIATION OF 4 READINGS OF AN ANGLE FROM ITS ADJUSTED VALUE SEC. −

Fig. 8. Six original quadrilaterals

Statistical Analysis of Results of Accurate Triangulation

For the first six quadrilaterals 36 independent angles were measured by observers A and B, twice each, making a total of 144 readings. For the next two quadrilaterals observer A made four readings for each of ten angles. For the last two quadrilaterals observers A and C made two readings each for each of ten angles.

In each case the four readings of any angle were meaned to give a mean observed angle, which was adjusted as described previously. The adjusted figures are so redundant that for the statistical analysis the adjusted angles are assumed "true" angles.

Analysis of Results from First Six Quadrilaterals

Fig. 8*A* is a frequency curve for the deviations of the four readings of an angle from the arithmetic mean of those four readings. The standard deviation of the universe, from which the groups of readings of any one angle are samples of four, is approximately the square root of the average variance within samples.

If $\bar{x}$ = mean of four readings,
and x = any individual reading,

then $s^2 = \dfrac{\Sigma(x-\bar{x})^2}{3}$ where 3 is the number of degrees of freedom of the four readings, and s is the within-sample standard deviation.

The universe standard deviation σ is given by $\sigma^2 = \dfrac{\Sigma s^2}{n}$ where n is the number of samples. By this method the standard deviation of the universe of survey results is 1·5″.

An alternative method of obtaining an approximation for σ more appropriate to this case, is from the sample ranges. The mean range $\bar{w}$ of the 36 samples of four is 3·21″ and from tables

$$\sigma \simeq \frac{\bar{w}}{d_n} \text{ where } d_n = 2{\cdot}06 \text{ for samples of 4}$$

$$\sigma \simeq 1{\cdot}56''$$

In this case the universe standard deviation can be computed direct from the deviation of individual readings from their finally adjusted value. Fig. 8*B* is

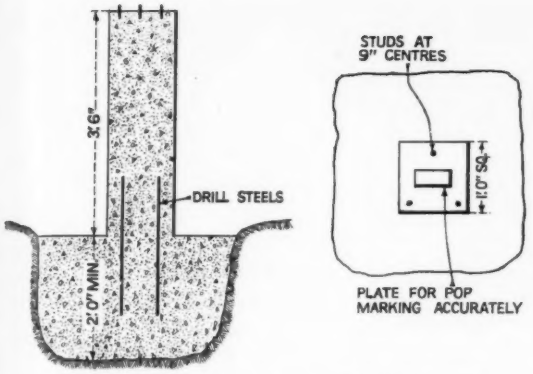


Fig. 9. Permanent stations on buttress axes

a plot of these deviations. By direct calculation $\sigma = 1{\cdot}83''$.

Had the number of readings m in the samples been greater than four, then the means of those samples would have been distributed with standard deviation $\sigma / \sqrt{m}$, the standard error. In this case the standard error can be calculated direct from the deviations of means of four readings of an angle from the finally adjusted value of that angle. The standard error was found to be $e = 1{\cdot}3''$.

Fig. 8*B* is somewhat asymmetrical, with a peak towards the negative deviations. Due to micrometer run error the expected average deviation on any angle is $+0{\cdot}05''$, *i.e.*, if chance causes alone are operating the peak of the frequency curve would be expected at a universe mean of $\mu = +0{\cdot}05''$. In this case the mean $\bar{x}$ of 36 deviations of mean observed angles is $-0{\cdot}25''$. A test can be applied to find if such a mean is significantly different from μ. Assuming no assignable cause the deviation of $\bar{x}$ from μ in standard measure is:

$$u = \frac{\bar{x} - \mu}{e / \sqrt{n}}$$ where n = number of mean observed angles.

$$\text{In this case } u = \frac{-0{\cdot}25 - 0{\cdot}05}{1{\cdot}3 / \sqrt{36}} = -1{\cdot}38.$$

The probability of such a value occurring is 17 per cent. and there is no evidence to suggest that the hypothesis of no assignable cause is false.

A check can now be made on the empirical range limit of 6″ applied to the four readings of an angle throughout the survey. From a table for control chart limit lines for range the values given in Table II were obtained.

TABLE II

No. in sample	Lower Limits		Upper Limits	
	Outer	Inner	Inner	Outer
	$D_{0{\cdot}001}$	$D_{0{\cdot}025}$	$D_{0{\cdot}975}$	$D_{0{\cdot}999}$
4 - - - -	0·20	0·59	3·98	5·31
$\sigma D = 1{\cdot}83$ D	0·37″	1·08″	7·29″	9·7″
No. of ranges occurring outside lines out of 36 samples - -	0	1	0	0

Thus with the standard deviation of individual readings obtained, a range of 7·3″ or more can be expected once in 40 groups of four readings of an angle, due to chance causes alone. The value of 6″ taken as the maximum permissible, beyond which assignable causes are probably acting, is therefore reasonable, but 7″ might have been even more suitable.

Analysis of Later Work

The standard deviation of mean observed angles taken by observer A alone was 1·2″, and that of observers A and C was 1·24″. Using a standard deviation of mean observed angles of 1·3″, as obtained for the original six quadrilaterals, the probabilities of the deviation of a mean observed angle exceeding a certain amount were obtained (Table III). The end column shows the number of actual deviations of such magnitude obtained from all 56 mean observed angles. Deviation $= x - \mu = u\sigma$.

TABLE III

Probability	u	$u\sigma$	No. of deviations exceeding $u\sigma$ out of 56
10%	1·64	2·13″	6
5%	1·96	2·54″	2
2%	2·33	3·02″	1
1%	2·57	3·34″	1

Value of Statistical Analysis

Once an observer has determined the standard deviation σ of individual readings he can expect to obtain with a given precise instrument under constant conditions, he can quickly assess the following valuable facts:—

(1) The number of readings required to attain a certain degree of accuracy. If m readings are made of each angle, where $m > 4$, then the means of the m readings are distributed with standard deviation $\sigma / \sqrt{m}$ and the probabilities of certain magnitudes of error can be read from tables.
(2) The allowable range of his m readings of an angle.
(3) The comparison between himself and another observer using the same instrument.
(4) The comparison between two instruments he is using himself.
(5) If conditions are not as when σ was determined, how much they are likely to affect his results.
(6) The accuracy of computing which is justified.
(7) The presence of a bias at any time.

Statistical analysis can thus be a powerful aid to a surveyor.

To be continued

Texrope V-Belts. High-capacity "Texrope" belts are described in a bulletin (No. 20B7786) issued by the Allis-Chalmers Manufacturing Company. These belts are claimed to be incapable of accumulating static electrical charges and to have oil-, heat- and weather-resisting qualities.

Howard Clayton-Wright Limited have issued a folder to call attention to their Clatonrite "O" rings which, constructed from resilient material with excellent wearing and temperature-resisting qualities, are designed to meet a wide range of applications for sealing joints, glands, etc.

Fig. 1. Aerial view of Davis dam, power plant, forebay channel, spillway, and related structures

The Davis Dam Project

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THE Davis Dam Project, a Bureau of Reclamation multiple - purpose development on the Colorado River near Kingman, Arizona, was dedicated on December 10, 1952. Governors of western states of the United States joined with representatives of the Republic of Mexico and United States Government officials in the ceremonies celebrating the completion of Davis Dam and power plant, the principal features of the project.

The dedication culminated many years of effort directed toward utilising and regulating the flow of the lower Colorado River. Construction of Davis Dam virtually completes the development of the river from Hoover Dam to the Mexican border, taking its place as one of the series of dams between the Grand Canyon and the point at which the river flows into Mexico. This series includes the Hoover, Davis, Parker, Headgate Rock, Imperial, and Laguna Dams.

Davis Dam project is a major contributor to the development of the lower Colorado River for hydroelectric power. In addition, it serves to re-regulate the flow of the main stream of the Colorado below the Hoover Dam. Davis Dam contributes to flood reduction, navigation improvement, irrigation and domestic water supply, silt-pollution reduction, recreation, and wildlife protection, as well as other related conservation purposes. The dam also serves an important function by providing for the accurate metering of water to be passed downstream in accordance with the treaty agreements between the United States and Mexico.

Davis Dam is in Pyramid Canyon, 67 miles downstream from Hoover Dam, and 88 miles above Parker Dam. It is about 10 miles north of the point where the boundaries of Arizona, Nevada, and California meet.

History

Davis Dam project was originally authorised as the Bulls Head project. it was later renamed in honour of Arthur Poweil Davis, who from 1914 to 1923 was Director of the Reclamation Service (predecessor agency of the Bureau of Reclamation). This memorial was bestowed on Mr. Davis in recognition of his

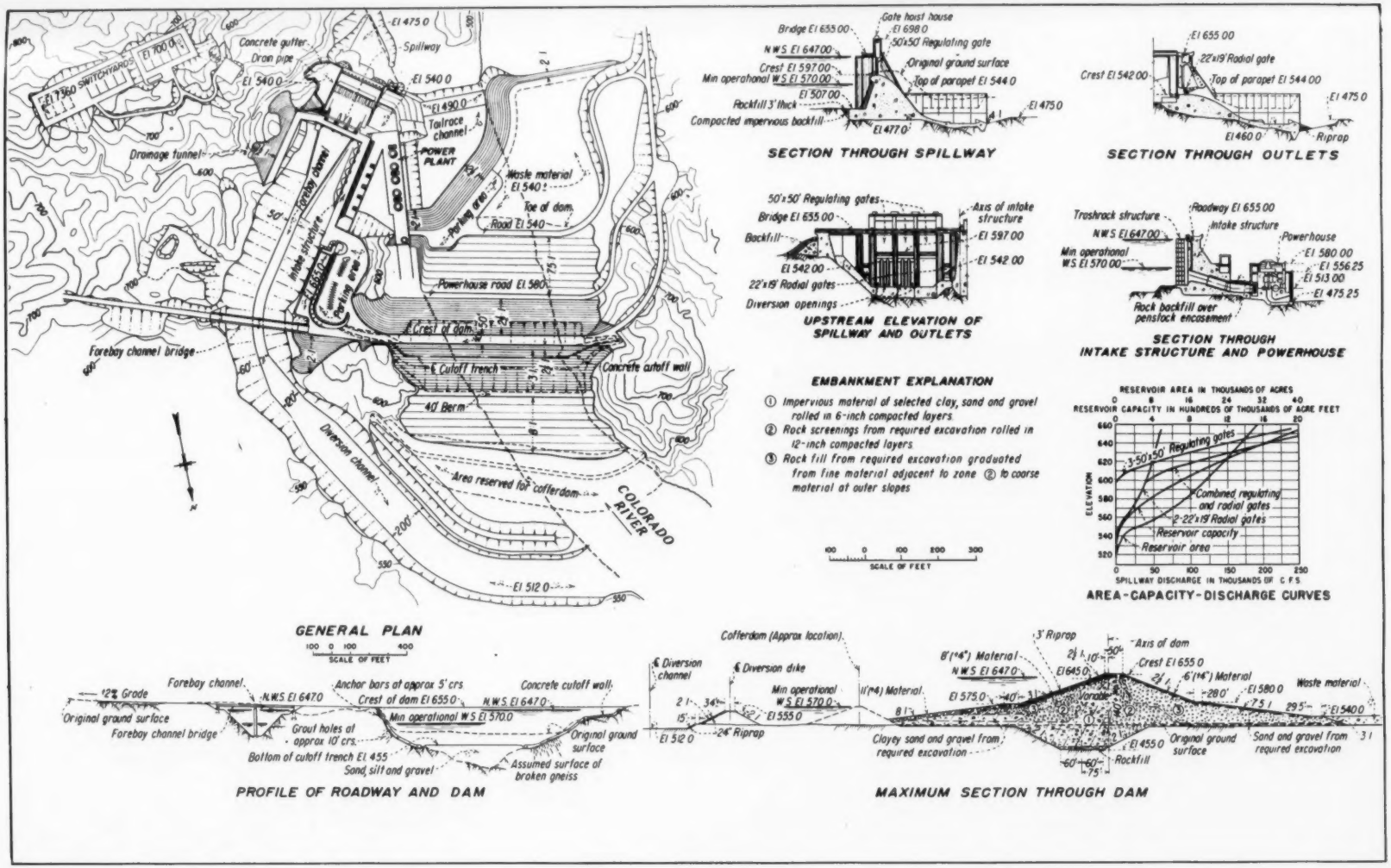

Fig. 2. Plan and details of the Davis dam

pioneering work in initiating and guiding the planning which ultimately led to the building of the dams and irrigation works along the entire reach of the lower Colorado River.

The Reclamation Service first investigated a possible dam site at the lower end of Pyramid Canyon in 1902. Further investigations were conducted in the 1920's. Results of these and other studies culminated in the Boulder Canyon Project Act of 1928, which authorised construction of Boulder Dam (Hoover Dam), and directed the Secretary of the Interior to make further investigations and report on the feasibility of projects to utilise the water of the Colorado River and its tributaries. In 1931, construction of Hoover Dam was begun in Black Canyon above the Davis Dam site, thereby establishing the high-water limits of the downstream reservoir development. Since a re-regulating reservoir was unnecessary until Hoover Dam controlled the Colorado River, no further studies were made for the Davis Dam development until the construction of the Hoover Dam was completed.

Explorations at Pyramid Canyon were resumed in 1939, and a site was selected for construction of Davis Dam. On April 26, 1941, the project was authorised by the Secretary of the Interior, under provisions of the Reclamation Project Act of 1939. This act provided that, if the project were feasible from an engineering point of view, and if repayment of construction costs would be possible within a 40-year period, the Secretary of the Interior could authorise construction by submitting a report to the President and to the Congress of the United States. In determining the feasibility of the project, no allocation of costs was made to benefits other than power. The reimbursable portion of the construction costs is to be repaid from net power revenues.

Reservoir

The Davis Dam project is designed to utilise stream flow of the lower Colorado River after it has been released from Lake Mead, the reservoir created by Hoover Dam, there being no tributaries entering the reservoir between the two dams. Lake Mead has a capacity of 32,359,000 acre ft. of water and controls almost completely the main stream. Releases from Lake Mead are governed by the requirements of irrigation and domestic water users downstream, those of flood control, and those of power generation. These are made in accordance with the Colorado River Compact, which provides for the distribution of the water of the Colorado River between the upper and lower basins of the river.

Lake Mojave, the reservoir formed by Davis Dam, submerges Cottonwood Valley upstream from Pyramid Canyon, traverses Painted, Eldorado, and Black Canyons, and, when full, backs up to the tailrace pool at Hoover Dam. At normal water-surface elevation Lake Mojave covers about 28,500 acres. It is nearly 4 miles wide at its widest point, 67 miles long, and contains 1,820,000 acre feet of storage. The active storage capacity between the minimum power-head level (elevation 570) and normal water surface level (elevation 647) is 1,600,000 acre feet.

Reservoir operation studies were made for Lake Mead based on run-off conditions for the 44-year period from 1897 to 1940. The irrigation diversion and the consumptive use of water in the upper Colorado River Basin will increase in the future until limitations provided in the Colorado River Compact are reached. Therefore, the water supply studies for the Davis Power Plant were based on estimated average conditions of diversion and consumptive use as estimated for the year 1945 and for the year 1985.

In years of low run-off, the entire annual stream flow at Davis Dam can be used for power generation. In years of high run-off part of the releases from Lake Mead will be needed for flood control purposes at discharges too high for power generation at Davis Dam. The long-time average annual flow usable for power generation was estimated at 12,500,000 acre feet under 1945 conditions and 9,500,000 acre feet under 1985 conditions.

At the present time (1953) the available active capacity in Lake Mojave not needed to regulate water for irrigation and other purposes is used to regulate releases from Lake Mead as nearly as practicable in conformity with needs of the power market. Since Lake Mojave smooths the fluctuation in the releases through the Hoover Dam power plant, operation of the two plants is coordinated to ensure the production of the maximum amount of firm power output in conformity with market requirements from both plants. Thus, the entire output from the Davis Dam power plant during years of low run-off can be classed as firm power.

Dam Site

During the investigations of the 1920's and 1930's alternative sites were explored in Pyramid Canyon above and below the present dam site, and alternative schemes and estimates were prepared for all the sites. Design studies were made on plans utilising concrete gravity dams, concrete arch dams, and earth dams layouts. These studies showed that construction of a concrete dam at many of the sites would prove costly because of the great depths to bedrock compared to the total height of the dam. In addition, the advantageous use of materials excavated from the appurtenant structures for use in constructing an earth dam placed it in economic favour over a concrete dam. For these reasons an earth- and rock-fill dam was selected.

The Davis Dam site occupies a unique position in Pyramid Canyon in that the present river gorge is crossed by an ancient river channel. This old buried channel lies east of the present channel upstream from the dam and west of the river downstream from the dam. Bulls Head Rock, just upstream from the dam, and from which the original project name was derived, divides the present river channel from this ancient stream bed. The old and new channels in plan take on the shape of an X, the dam being situated where the two cross, and where a single gorge exists in the canyon.

The canyon at the dam site is about 800 ft. wide at the river level, from which elevation the depth to bedrock in the river channel is in excess of 200 ft. The foundation area of the dam proper consists of recent river-channel and terrace deposits overlying a gneissic granite bedrock which has been intruded by large rhyolite porphyry dikes and smaller basic dikes. The alluvial deposits which make up the overburden are chiefly silt, sand, and gravel in the present river channel and in the now-buried former channel. Beneath these sediments, and in places protruding

through them, is the principal foundation rock of the dam site. This rock is a porphyritic granite gneiss and is a coarse-grained rock showing a crudely laminated or banded structure obscured in many places by severe crushing and general weathering.

The rock in both the Nevada and Arizona abutments for Davis Dam is also composed of porphyritic granite gneiss. Both abutments above the river are steep and bare and are severely broken by persistent jointing, and containing minor, clay-filled faults and soft andesite dikes. The Arizona abutment rises to a level slightly higher than the dam and then continues as a ridge for some distance back from the canyon. The Nevada abutment rises to a broad knoll about 100 ft. higher than the dam.

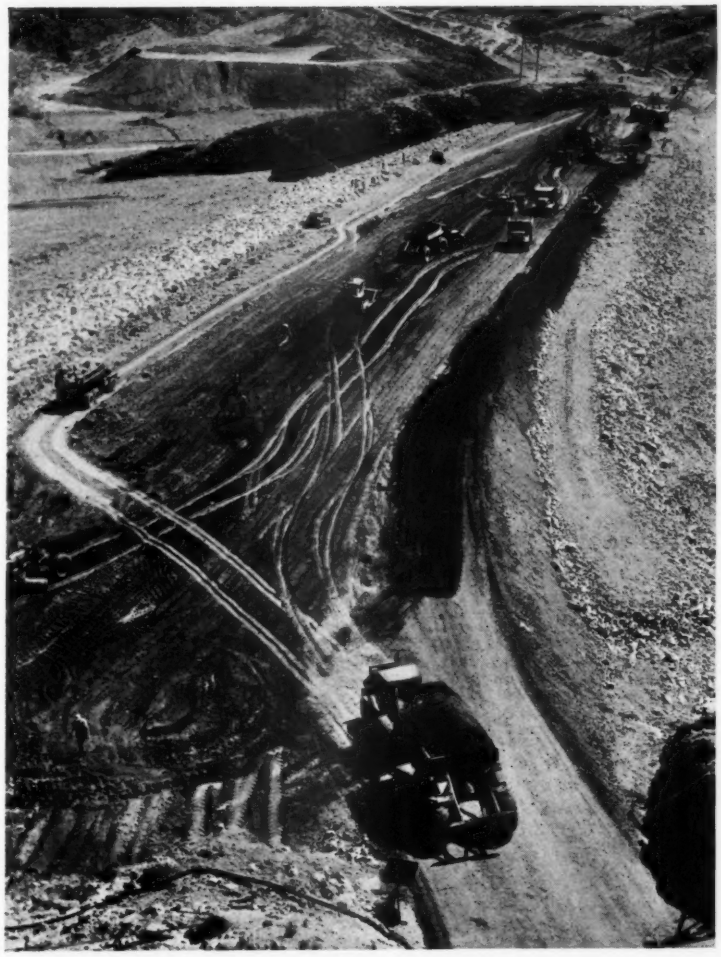

Fig. 3. Davis dam embankment construction nearing completion in April 1949

The Dam

The arrangement of the Davis Dam structure is considered unusual in that the plan does not follow the layouts ordinarily employed in dam construction. The scheme entailed, in effect, the digging of a new river channel around a stretch of the existing river, the use of the material excavated from this new channel to dam up the existing canyon, and the construction of concrete control structures across the newly created channel.

The dam is a zoned earth- and rock-fill embankment rising approximately 140 ft. above the normal river bed and 200 ft. above the lowest point in its foundation. It is approximately 1,400 ft. thick at river level and 50 ft. wide at the crest. The top of the dam is bounded by a concrete parapet and a sidewalk along the upstream side and a concrete curb along the downstream side, the 1,600 ft. crest length being surfaced to accommodate a transcontinental highway.

Of the several storage dams built on the Colorado River, the Davis Dam is notable in that it is the only one that rests on original sand and gravel river fill, without the conventional cut-off extending to the rock foundation. However, a cut-off trench about 50 feet deep and 120 ft. wide at the bottom, with 2 to 1 side slopes, was excavated under the dam to intercept permeable surface beds of the river fill and to minimize differential settlement of the embankment. The trench was backfilled with impervious materials and the centre core was continued upward from this backfilled trench. As compensation for the omission of the deep cut-off, a 10 ft. layer of the impervious material was extended over the entire foundation of the dam upstream from the trench, and a layer of sand and gravel was placed over the foundation downstream from the trench. The upstream pervious layer lengthens the percolation path and reduces seepage, while the pervious downstream layer acts as an inverted filter to dissipate water pressures which would normally build up in a foundation composed of lenses of material of varying permeability.

The dam embankment consists principally of materials produced in excavating the diversion channel and structure foundations, supplemented by minimum quantities of selected materials not available from required excavations. Sand and gravel taken from the cut-off trench were placed in the filter zones of the dam. The material obtained from the channel and structure excavations, composed mainly of soft to hard gneiss which broke up during blasting and handling, provided material for the semipervious and pervious zones of the dam. Material for the impervious zone was taken from borrow-pits about 3 miles upstream from the dam. Riprap was obtained from a quarry about 7½ miles south of the dam.

The impervious materials for the centre core of the dam, the backfilled cut-off trench and the upstream foundation blanket, composed of a selected mixture of clay, silt, sand and gravel, were moistened

and rolled into 6-inch compacted layers. The semi-pervious zones adjacent to the impervious core consist of rock screenings ranging from dust to 4-inch fragments compacted in 12-inch layers. The pervious zones which provide the stabilising bulk of the dam are unscreened rock materials deposited in 2 ft. layers without compaction. Layers of screened rock, 8 and 6 ft. thick respectively, complete the upstream and downstream faces of the dam. The upstream face above minimum water level for power production is covered with a 3 ft. layer of large rock riprap. Two berms, at elevations 580 and 540 on the downstream face of the embankment, accommodate 24 ft. bituminous-surfaced access roads to the upper deck and machine-shop deck of the power plant.

On the rock abutments for the embankment, concrete cut-off walls are trenched 3 feet into the foundation rock and protrude 10 feet into the impervious zone material. These walls extend from the elevation of the bottom of the cut-off trench to the top of the dam. Holes were drilled under the cut-off walls and grout was forced into the underlying rock, with the line of holes on the left abutment tying into a grouted cut-off curtain encircling the forebay.

The principal quantities involved in the construction of the dam were 500,000 cu. yards of cut-off trench excavation, 1,000,000 cu. yards of impervious fill and 2,800,000 cu. yards of rock fill and riprap.

Diversion and Forebay Structures

The channel excavated around the Arizona (left) abutment of the dam served initially as a diversion channel to bypass the flows of the river during construction of the dam embankment and finally became the forebay channel for the spillway, outlet works, and power plant. The channel is more than $\frac{3}{4}$ of a mile long, and at its downstream end is enclosed by a U-shaped arrangement of gravity-type concrete structures. The right side of the combination is the power plant intake structure or penstock dam; the centre section of the U, located directly across the end of the channel, is the spillway and outlet structure; and the third side of the system, a plain gravity wall, serves to complete the enclosure.

The channel at the upper end begins at the right angles to the river just below Bulls Head Rock and follows Bulls Head Wash for about 2,000 ft., crossing the area occupied by the ancient river. The channel in this portion is comparatively shallow, is excavated to river bed level in silt and sand, and is 200 ft. wide at the bottom with 2 to 1 side slopes. A diversion dike formed from the excavated materials was constructed on the right side of the channel to confine the water in the channel and to act as a protection for the upstream cofferdam. The dimensions of this entrance portion of the channel were so chosen that the diversion flows did not exceed scouring velocities along the silt and sand banks.

The portion of the channel which curves and cuts through the ridge to the left of the dam is excavated in rock. The grade through this stretch drops about 10 ft. below that of the upper channel and the bottom width narrows to 50 ft. The side slopes are 1 to 1 and the channel has a depth in excess of 175 ft. The downstream portion of the channel which forms the immediate forebay for the control structures widens so as to provide a basin about 500 ft. long and 350 ft. wide in front of the structures. Except for the side slopes and bottom immediately upstream from the structures, the channel is unlined.

Fig. 4. Aerial view of Davis dam and associated structures, taken in March 1949, showing the S-shaped construction trestle

The power plant intake structure is a mass concrete gravity dam over 500 ft. long, varying from a minimum height of 135 ft. to a maximum height of 163 ft., and having a base up to 133 ft. wide. The cross section is of conventional shape, having a nearly vertical upstream face and a 0·7 to 1 downstream face. The crest carries a 30 ft. wide roadway, and a transformer and take-off tower deck is integral with the toe of the structure. This structure contains five 22 ft. diameter steel penstocks spaced at 60 ft. centres, through which the water passes to drive the turbines in the powerhouse. Each penstock opening is protected by a semicircular trashrack and a 17 by 35 ft. fixed wheel gate operated by a hydraulic hoist controls each penstock entrance. The power plant is placed along the original river edge immediately downstream from the main dam embankment and opposite the intake structure.

Placed across the downstream

end of the channel is a concrete gravity structure about 355 ft. long, consisting of a centre overflow or spillway section, and flanking abutment sections, each of which contains a radial gate outlet. This structure rises 221 ft. above the foundation, which is 170 ft. below the normal water surface. The overflow section is ogee-shaped and is surmounted by three 50 by 50 ft. fixed-wheel gates, with their sills at the ogee crest elevation 597 and supported between piers 10 ft. thick. These piers rise to support the hoist deck 100 ft. above the crest. The outlet openings on each side of the overflow section are 22 ft. wide and 19 ft. high, the sills of the openings being at elevation 542; that is 55 ft. below the crest of the spillway. The 22 by 19 ft. radial gates which control the flow through these openings are housed within chambers formed inside the abutment sections.

Fig. 5. Aerial view of the forebay channel

The combined spillway and outlet structure terminates in a stilling basin, 246 ft. wide, which accommodates discharges from both the spillway crest and outlet openings, and has been designed for a flow of over 175,000 cusecs at normal water surface elevation 647. The stilling basin is 170 ft. long which, together with the ogee dam, results in a structure 380 ft. long, measured in the direction of flow. The floor of the basin is 137 ft. below the spillway crest and about 50 ft. below tail water elevation.

Flanking the left side of the forebay is a gravity wall about 400 feet long and roughly of triangular cross section, this being necessary to dam a low place in the natural rock ridge forming the left side. This wall is placed about 40 ft back from the top of the 1 to 1 excavated channel slope. To minimise seepage through the rock beneath the wall, the adjacent slope of the channel is paved with an anchored and reinforced concrete lining. The outside face of the gravity wall is backed up with a rock-fill embankment to form a 30 ft. wide berm.

Bridging the spillway gate openings is a 30 ft. wide deck, to complete a continuous roadway across the operating structures.

About 1,100 ft. upstream from the spillway structure the forebay channel is crossed by a twin-span deck plate girder bridge, 420 ft. long, having a 30 ft. roadway and two 5 ft. walkways. The central pier supporting the spans is placed in the centre of the channel, and measures 152 ft. from the channel floor to the top. This bridge, which was recently singled out by the American Institute of Steel Construction to receive its annual Aesthetic Bridge Competition Award, carries the transcontinental highway which crosses the main dam embankment.

Power Plant

With placement of Davis Dam power plant in full service on June 17, 1951, the annual rate of output of Colorado River plants was increased by about a billion kWh. The plant, containing five 45,000 kW units, is the Bureau of Reclamation's fourth largest hydro-electric development. It is situated on the Arizona side of the Colorado River immediately downstream from the main dam embankment and adjacent to the concrete intake structure. The intake and power plant structures join in their downstream ends at an angle of about 30° between the axes, and the plant itself is of the semi-outdoor type. It is constructed of reinforced concrete and comprises three separate parts—the service bay, generator bay, and control bay structures, each separated from the other by a 1 in. expansion joint. The building is 615 ft. long and 114 ft. high above foundation.

Weather conditions at Davis Dam are mostly arid and warm, and the selection of an outdoor type plant, where the top deck of the plant is placed at the base level of the generators, was indicated. Because of the extreme summer heat, however, it was considered advisable to protect the generators by insulating their housings or by enclosing them within the building. A semi-outdoor design, containing the generators within the building, was consequently chosen, the top deck being placed immediately above the generator level. A 325 ton capacity gantry crane located on the roof traverses the entire length of the plant to aid in installing and servicing the plant equipment.

The power plant structure is of the conventional reinforced concrete type, with steel deck girders covered with a reinforced concrete deck. To eliminate the transmittal of excessive stress to the power plant proper, the thrust from the penstocks entering the plant is taken up by massive concrete anchor blocks between the intake structure and the power plant. An expansion joint is provided between the penstock and the spiral turbine casing.

On the top deck level of the power plant, hatches are located over each generator to permit installation of the turbine and generator parts from the top deck of the plant, and additional hatches are provided between alternate generating units to enable equipment

to be lowered or transferred into the power plant interior rooms and galleries after the generators are installed.

The plant governor gallery, situated below the generator floor level, contains the governors for each turbine, and is provided with a 5 ton travelling crane for servicing the area. Each turbine is designed and constructed so that, after removal of the intermediate shaft, all removable parts, including runner, main shaft, main guide bearing, head cover, gate mechanism, and the wicket gates can be raised from the turbine pit and moved along the gallery by means of the travelling crane. These turbine parts can then be hoisted through the hatchway by the 325 ton gantry crane and deposited upon the powerhouse deck. This may be accomplished without disturbing the generator; however, if the generator is dismantled, the parts may be hoisted with the gantry crane through the 21 ft. circular pit below the generator and through the generator stator. The 5 ton travelling crane can also be interchanged to any position along the gallery without removing the generator shafts by lifting and transferring it through the hatchways with the gantry crane.

The turbine installation for the Davis plant consists of five vertical-shaft, Francis-type, 94·7 r.p.m. turbines with riveted plate-steel spiral case and elbow-type draught tube. Each turbine has a capacity of 62,200 h.p. at full gate and 120 ft. effective head, and is designed for best efficiency at 127 ft. effective head. Acceptance tests made on the turbine of Unit No. 2 using the Gibson method of water measurement indicated a maximum hydraulic efficiency of 92·3 per cent. when developing approximately 62,000 h.p.

The Davis turbines are the largest in physical size in any Bureau power installation, the complete turbine weighing about 622 tons, and the runner about 70 tons. Because a solid one-piece runner was preferred, its size was dictated by railroad clearances between eastern shipping points and Davis Dam. A cast-steel runner of 17 ft. diameter was selected and was shipped mounted on special girders suspended between two flat cars. The spiral casings are of plate-steel butt-jointed riveted construction, each with an intake section 22 feet in diameter. Each case is made of plates ranging from $1\frac{3}{8}$ in. to $\frac{5}{8}$ in. in thickness and weighs about 370 tons complete with stay ring and bulkheads.

The following erection procedure for the spiral case was employed. The speed-ring was assembled, supported by 24 jacks, and was then bolted to the draught tube liner. Next, the scroll case was assembled and mounted to the speed ring, being supported by 27 additional jacks placed around the periphery of the case. Temporary steel plate bulkheads, that closed off the intake of the case and the annular opening in the stay ring, were then installed, converting the case into a watertight pressure vessel. Water was then introduced to the case at a pressure of 55 lb. per sq. in., and after final alignment the case and supporting jacks were completely encased in concrete. The combined weight of the case, bulkheads, and water which the jacks had to support was approximately 1,500 tons.

Each of the five generators is rated at 45,000 kVA, at unity power factor, 13,800 V, 3-phase, 60-cycles, 94·7 r.p.m. The total net weight of a generator and exciters is approximately 625 tons. Diameters of the generators are respectively: rotor, 29 ft. 3 in.; stator, 35 ft.; and air housing 44 ft. The generator arrangement is of the conventional design; an upper guide and thrust bearing are located above the rotor, and a guide bearing below the rotor. The thrust bearing thus carries the entire weight of the rotating parts of the generator and turbine, in addition to the hydraulic thrust. Each generator is excited by a direct-connected vertical shaft, shunt-wound type, 330 kW, 250 V, main exciter mounted on top. The main exciter in turn is excited by a direct-connected, compound-wound 12 kW, 250 V, self-excited pilot exciter mounted on top of the main exciter.

Fig. 6. Assembly of the scroll case for the first of the 45 MW generating sets

Each generator is equipped with an enclosed cooling system, complete with eight separate water-cooled heat exchangers spaced about the periphery of the generator and a metal air housing. Blades attached to the rotor act as a blower to circulate the air through the stator into the metal housing and then through the coolers.

Gantry Cranes

The 325 ton capacity gantry crane is the largest of its type installed on a Bureau project. It consists essentially of two movable trolleys supported on a travelling gantry. Each trolley is equipped with a main hoist, an auxiliary hoist, a drive mechanism, and four-wheel mounting for transverse travel. The crane is controlled from an operator's cab mounted

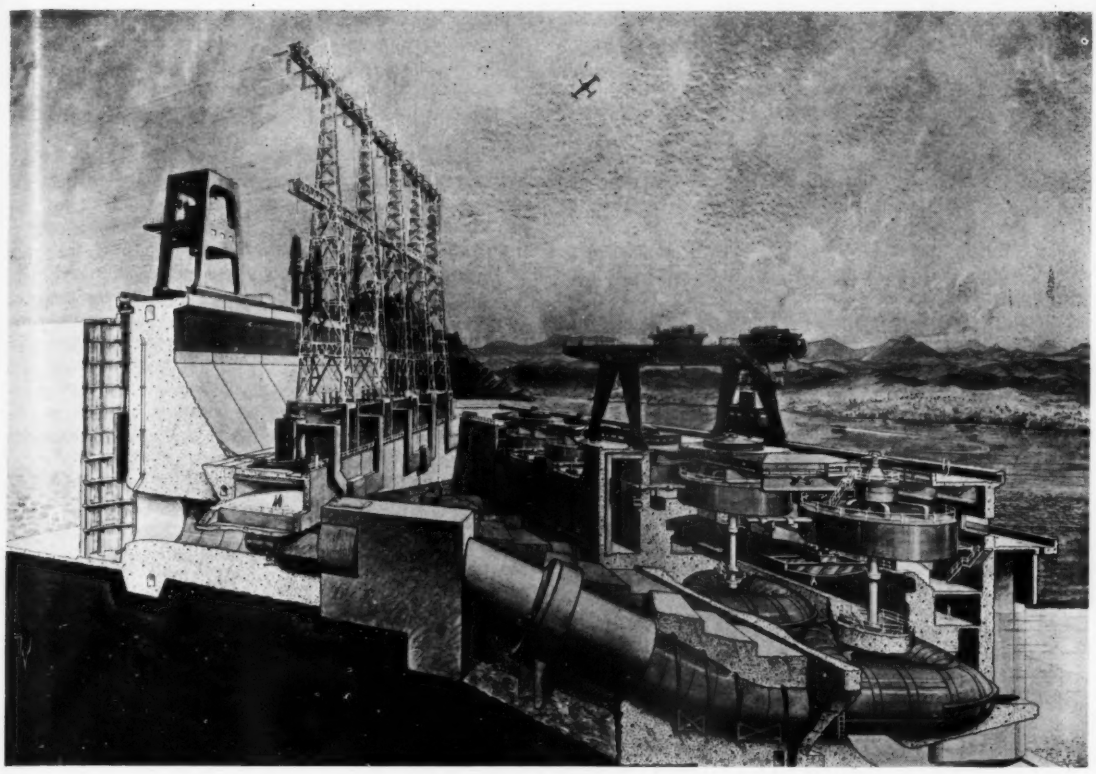

Fig. 7. Schematic view of the power plant and intake structure

between the downstream gantry legs. All hoists and travel drives are electrically operated.

A 125 ton capacity gantry crane is also provided for the erection, installation, and maintenance of the penstock fixed-wheel gates and hoists, and for the installation and removal of the penstock intake stop logs. The gantry moves the full length of the intake structure, serving five gate units. An auxiliary hoist of 25 ton capacity is provided to raise and lower stop-log sections. This hoist moves in an upstream and downstream cross-travel motion to unload and handle miscellaneous parts of the intake structure deck. A cantilever section on the upstream side of the crane permits the auxiliary hoist trolley to overhang the trashrack structures for handling the stop logs.

Switchyards and Cable Gallery

The switchyards which provide terminal facilities for the outgoing transmission lines are located on a high point across the ravine east of the forebay structures. They were formed by the excavation and the levelling of several benches along a ridge; two benches contain the switchgear for a 230 kV yard at elevations 700 and 736, and a smaller bench provides for a 69 kV yard at elevation 675. Five steel towers located on the slope east of the forebay channel carry the transformer circuits from the take-off towers on the intake structure to the switchyards. Control cables which lead from the power house to the switchyards are carried up a shaft in the southern end of the intake structure, across the spillway under the spillway bridge, then through the left abutment of the spillway, and through a control cable tunnel which follows the ground profile across the ravine.

Power Market

Although the discharge from the reservoir at Davis Dam is co-ordinated with that from Lake Mead for the purpose of regulating the flow to the best advantage of downstream irrigation and other uses, the power output is interconnected with the Parker Dam plant. The combined output of the Davis and Parker plants is used to supply a large part of the power requirements of southern Nevada, central and southwestern Arizona, and parts of Southern California.

Transmission lines emanating from the Davis Dam power plant interconnect with the Hoover and Parker systems and service load centres at Phoenix, Tucson, and Yuma, Arizona, the Imperial Valley in California, and the Gila Valley near Yuma. More than 1,400 miles of transmission lines are included in the Davis project system.

Construction

The contract for the construction of dam and power plant was awarded to the Utah Construction Company in June 1942. After a considerable amount of preparatory work and commencement of the forebay channel excavation, the contract was terminated early in 1943 because of the war emergency. Work was resumed in March 1946 when the same contracting firm was awarded the contract for the dam's com-

pletion. Construction of the dam embankment was finished in May 1949, and the entire contract completed in December 1950.

Because of the schematic arrangement of the structures, construction was confined to three phases, dictated by the requirement for handling the river flows during the construction period. The first phase included the digging of the diversion channel and the construction of the foundation portions of the forebay structures in preparation for the diversion of the river. During the second phase, while the water was being diverted through the newly created channel, the original river channel was unwatered, the earth dam was built, and the upper portions of the forebay structures across the new channel were completed. The final phase was the closure of temporary openings which were left in the spillway structure to handle the river flow while the second phase work was being accomplished.

The first construction phase involved the excavation of over 3,800,000 cu. yards of earth and rock material, a large portion of which was stock piled for later use in the dam embankment. About half of the excavated rock material was sorted into two sizes by grizzlies and then stock piled separately. Excavation averaged over 10,000 cubic yards per day, and at times as many as 25,000 cu. yards of material were handled in a 24-hour period. In doing the work the contractor employed four power shovels, forty 10 to 13 cu. yard dump trucks, and eleven scraper earth movers.

After completion of the excavation, the foundations for the concrete structures were intensely grouted, to tighten the shattered and jointed rock. Concrete placement in the lower portions of the forebay structures and the forebay lining was begun in January 1948 and six months later was completed to a height sufficient to permit the diversion of the river through the new channel and through six 13 ft. wide temporary openings in the spillway crest structure.

In the second construction phase, the river was diverted into the new channel by the construction of cofferdams both upstream and downstream from the dam foundation area. The upstream cofferdam, completed first, was constructed by initially building a timber pile trestle across the river from which earth and rock materials were dumped to barricade the river channel. This closure was effected while the river flow was as much as 24,000 cusecs. The closing of the final gap of the cofferdam was made under a differential head of 9 feet. The downstream cofferdam was constructed by similar methods. After the cofferdams had been built up and made relatively watertight, the dam foundation surface was pumped dry and a subsurface drainage system of 3,300 well points was installed to dry up the river bed materials so that excavation and backfilling of the cut-off trench could begin.

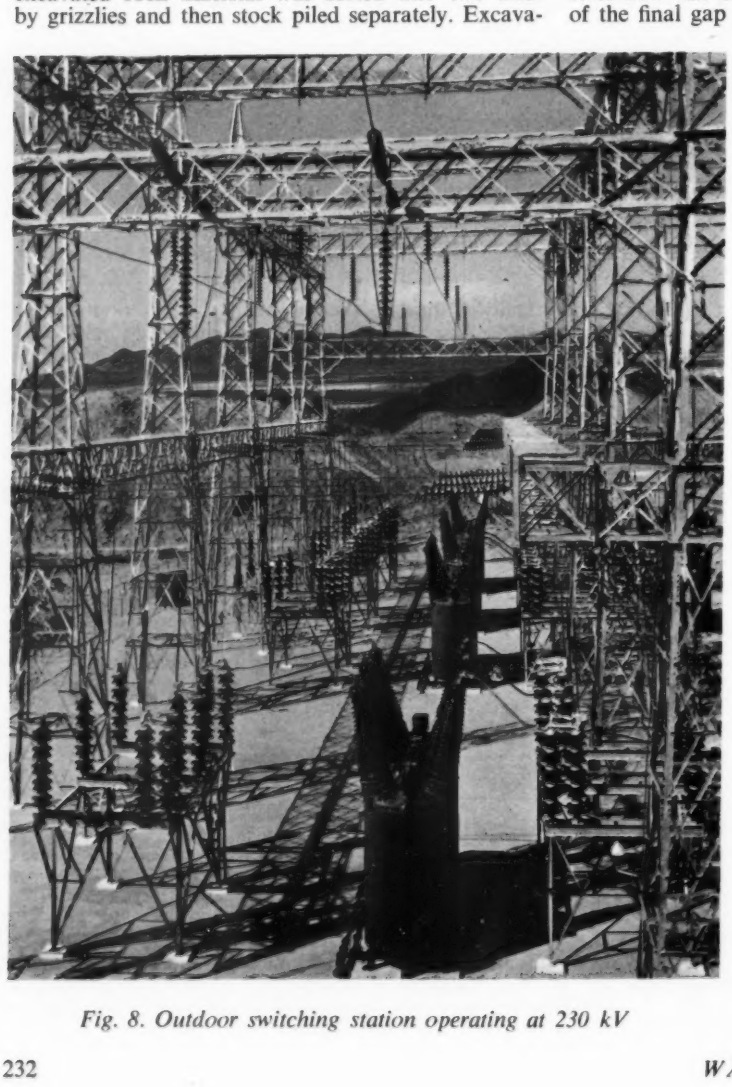

Fig. 8. Outdoor switching station operating at 230 kV

The river closure was completed in July and August of 1948, and the first embankment materials were placed during September. The cut-off trench was excavated and ready to receive the first layer of backfill late in October 1948. In April 1949, 10 months after diversion of the river, the dam embankment, totalling 3,800,000 cu. yards, had been completed to its full height. There were 770,000 cu. yards of embankment placed during the month of February 1949, which at that time established a record for embankment placement in a large earth dam.

During this second phase of construction, work on the forebay structures continued and the power plant structure was started. Concrete, forms, reinforcement, and other material required to build the spillway and intake structures were handled by two whirley cranes with 160 ft. booms, travelling on an S-shaped construction trestle 90 ft. high and 1,084 ft. long. The trestle adjacent to the intake structure had a branch to serve the power plant.

Two railroad tracks passed along the trestle and terminated at the 8 cu. yard capacity concrete mixing plant on the Arizona river bank about ¼ mile south of the structures. Transported on railroad cars, the buckets of concrete were picked up and spotted by the whirleys. Construction of the forebay structures and power plant involved the placing of about 600,000 cu. yards of concrete and over 25 million lb. of steel penstock, structural steel, and reinforcement steel.

The final phase involved the closure of the six temporary diversion openings and the completion of the spillway crest. During this stage the river flow was passed through the radial gate outlet openings. This work was accomplished from January to June 1950.

At peak periods, up to 1,300 workers were employed by the contractor, and some 150 by the Bureau. The contractor's camp on the Nevada side of the river a few miles below the dam was equipped with all the facilities usually established for a small town of about 3,000 population. A part of the Government camp on the Arizona side of the river was built as a permanent installation for housing the operation and maintenance personnel for the dam and power plant.

In addition to the two trestles which crossed the river at the cofferdam locations, two access bridges were provided downstream from the dam site, and a haul bridge spanned the upper end of the diversion channel.

Concrete

Aggregate for concrete was produced from natural deposits located on the Nevada side of the river some 3 miles downstream from the dam site. As a normal precaution against alkali aggregate expansion in the completed concrete structures, Type 2, modified, low-alkali cement was used in all concrete mixes. As an extra precaution, and to reduce the initial heat of hydration in the concrete, a calcined Puente shale Pozzolith admixture was used in the amount of 20 per cent. by weight of the portland cement.

The construction specifications required that the placing temperature of the concrete was not to exceed 80°F. Several measures were adopted to achieve this condition. As an initial step the contractor provided a wooden shed over the aggregate stock piles at the mixing plant to protect them from the intense heat of the desert sun. Sand was not shaded, however, since its insulation qualities prevented heat penetration to any great extent. During the hot summer months a refrigerating plant was used to cool the mixing water to a temperature of 40°F. At times, as much as 100 pounds of chopped ice per cubic yard of concrete were also used to bring the temperature of the mix down to the prescribed limit.

All mass concrete was cooled after placing by circulating river water, which seldom exceeded 65°F., through embedded tubing placed on the rock foundations and on the top of each 5 ft. lift. Such cooling was continued until the average temperature of the surrounding concrete was within 5°F. of the cooling water temperature.

Additional Construction Work

Under the original contract, as excavation work progressed, it became apparent that certain weaknesses, not completely disclosed by preliminary investigations, existed in the rock downstream from the spillway structure to the extent that it (the rock) was not considered capable of resisting the high velocity flows created at the end of the bucket apron as designed. Accordingly, a longer, hydraulic-jump, stilling basin was substituted for the original spillway bucket. Because the longer basin could not be constructed without interfering with the original contractor's downstream cofferdam and construction plant, and in order to avoid postponement of the initial diversion, it was decided to defer the completion of the stilling basin until all other construction was finished and the river flow could be diverted through the power plant turbines.

The stilling basin completion work was undertaken by separate contract in September 1951, and, in addition to construction of the reinforced concrete basin, involved the excavation of a considerable amount of material downstream from the spillway and in the river channel below the dam and power plant. This contract was virtually completed by the end of April this year.

Consultants and Contractors

All the design work and constructional administration were performed by the Bureau of Reclamation, private consultants only being employed in an advisory capacity to review the designs and make recommendations on problems which arose during construction. These consultants were: J. L. Burkholder, San Diego, California; O. Singstead, New York, New York; J. A. Beemer, Encinitas, California; C. P. Berky, Palisade, New Jersey; J. W. Vanderwilt, Denver, Colorado; J. L. Savage (former Chief Designing Engineer, Bureau of Reclamation), Denver, Colorado; and W. R. Young (also a former Chief Engineer, Bureau of Reclamation), Denver, Colorado.

The main contractors were as follows: construction of the dam and power plant — Utah Construction Company, San Francisco; installation of generators, non-embedded turbine parts, main transformers, circuit breakers, switches and miscellaneous electrical, hydraulic and mechanical equipment — Donovan-James-Wismer & Becker, St. Paul, Minnesota; turbines —Baldwin Locomotive Works, Eddystone, Pennsylvania; generators and power transformers—General Electric Company, Denver, Colorado; completing construction of spillway stilling basin—Grafe-Callahan Construction Company, Dallas, Texas.

Tekapo Scheme. A reprint from the English Electric Journal (Vol. XII, No. 7) gives an account of the Tekapo plant, which forms part of the Waitaki River development scheme in South Canterbury, New Zealand. The description, which is written by H. L. Bazalgette, A.C.G.I., M.I.E.E., A.M.Inst.C.E., and is essentially technical, refers in particular to two new 15,000 kW units that have recently been added to this station.

Earth-Moving Equipment. Two new catalogues have been published by Blaw Knox Limited, No. 104/1 dealing with the BK "Fifty" Excavator and No. 106 with the BK-12 Motor Grader. Both are handsomely produced and fully illustrated and give detailed specifications together with operational and constructional features. The action photographs which are reproduced show the machines being applied in an astonishing diversity of working conditions.

New Zealand's Biggest Power Project

An outline is given by L. R. Palmer of the Roxburgh development in the South Island, which is scheduled to commence operation in 1954 and will have an ultimate capacity of 320 MW.

HYDRO-ELECTRICITY is by far the biggest source of power in New Zealand. Total connected load is over 4·6 million kW and consumption averages more than 1,250 kW per head of population. At the end of the last financial year invested capital in the industry, which is virtually a State monopoly, stood at nearly £100 million and annual revenue at £4·54 million.

New Zealand is blessed with big reserves of water potential but the difficulty is to build generating stations fast enough to catch up and keep pace with the expanding demand. Since the war top priority in national works has been given to hydro-electric construction, yet power rationing is the rule in most parts of the Dominion.

Special attention has been given to electric power development in the North Island, which includes more than two-thirds of the Dominion's population, and, compared with the South Island, has more intensive systems of land use, especially in dairying, and a corresponding range of industrial capacity. Full utilisation of the major water-power resources of the North Island is in sight, and one of the problems of the next 20 years will be to find sources of power to meet future demands. At present the North Island has more than twice the installed generating capacity of the South, but by far the greater part of the hydro-potential lies in the South Island—and in the far south at that. Assuming that electricity will remain the chief source of power, two possibilities are in prospect: either economic activity will develop near available power supplies in the South, or power generated in the South Island will be transferred to the North by means of a cable laid across Cook Strait, which is less than 20 miles wide at its narrowest point.

The normal practice in New Zealand has been for the Ministry of Works to construct the hydro-electric stations as civil-engineering projects and then hand them over to the State Hydro-Electric Department, which installs the electrical gear and takes charge of their operation. Shortages of engineers, labour and materials have impelled the Government to modify this construction policy and resort to the employment of private contractors. The biggest and best example of this is the Roxburgh power project in Central Otago, near the southern end of the Dominion. There the biggest river in New Zealand, the Clutha, is being harnessed to ultimately develop 320 MW. It will be by far the largest single generating station in New Zealand; its output will be nearly half the Dominion's present installed capacity, and that may not nearly exhause the capacity of the Clutha.

This river, 210 miles long, flows almost across the broad base of the South Island from the Southern Alps to discharge into the sea at an estimated average rate of 2,000,000 cu. ft. per min. For power generation one significant fact is that the Clutha headwaters drain from three beautiful upland lakes, Wakatipu, Wanaka and Hawea. The volume of discharge from Wakatipu, 13,000 cusecs, is the largest in New Zealand. At a point on the river about 100 miles inland from Dunedin and the sea, and six miles above the old gold-mining town of Roxburgh, a site has

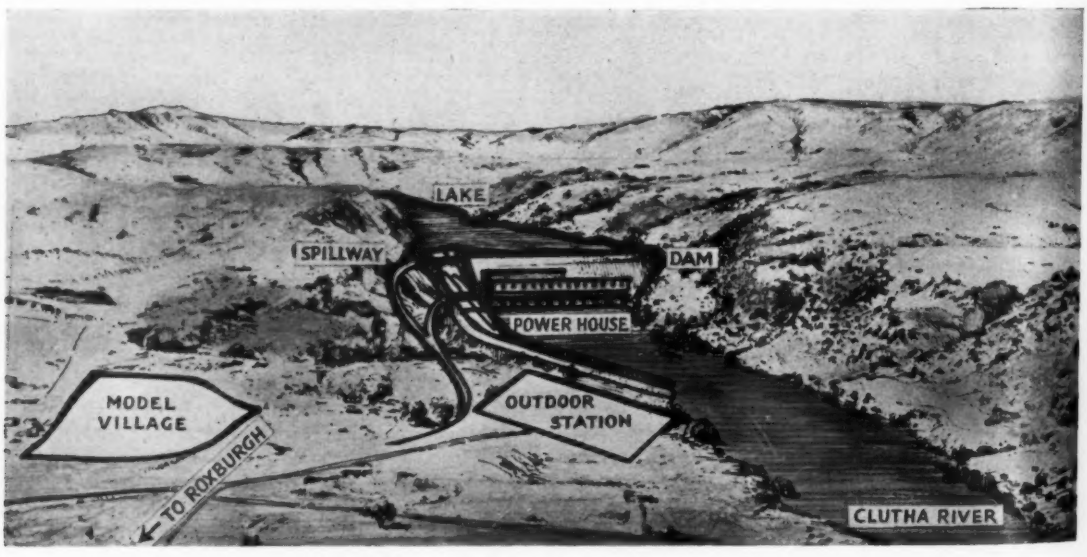

Fig. 1. Diagram of the Roxburgh power project

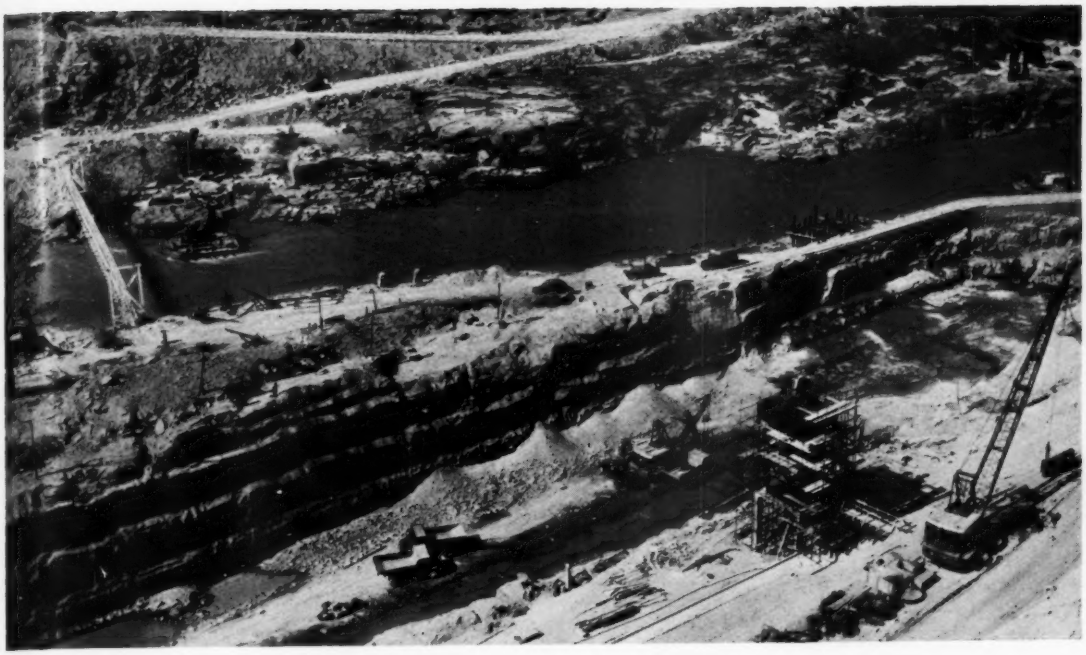

Fig. 2. Work in progress on the diversion channel alongside the Clutha River

Fig. 3. The upper end of the diversion channel near its junction with the Clutha River

Fig. 4. The Clutha River from the site of the power house

been selected for damming the river and building a power-house. The Clutha hereabouts issues from a gorge and flows fairly swiftly between narrow and well-defined banks to the broader valley below.

The site is only 300 ft. above sea-level. Rounded hills covered with grass or tussock, but no bush, rise to 3,000 ft. and are typical sheep-farming country. Rainfall is never above 20 in. The summers are hot and dry and the winters cold and dry. This gives a salubrious climate, with a high sunshine record, and makes the district particularly suitable for fruit-growing. Orchards on the low slopes or tucked into the folds of the valleys are a pleasing feature of the landscape.

To this site at the end of last September came a firm of overseas contractors to construct the dam, spillway and other associated works. The magnitude of the project is reflected in the contract price of £8,620,714, which, at the time it was let, was the second largest overseas works tender held by British enterprise. The firm is Cubitts and Zschokke, a New Zealand-registered subsidiary of two well-known European contractors, Holland, Hannen and Cubitts Ltd., of London, and Conrad Zschokke, of Zurich. July 1, 1955, is the scheduled date by which the lake should be full and the first generating machine running.

Ministry of Works' technicians, who have been on the site since 1949, had carried out a good deal of the preliminary work before the private contractors took over. A model village was built and now has a population of 3,000 people; extensive excavations for the diversion tunnel had been carried out and concreting of the channel had begun; the installation of the cableways, concrete batching plants, aggregate plants and bulk cement handling facilities had been put in hand. The Ministry of Works had also removed a quarter of a million yards of rock and had placed 100,000 of the 700,000 cu. yd. of concrete which, it is estimated, the job will require. Aggregate is freely available from ground worked over by the old gold dredges, some of which used to yield 400 ounces to the acre. Gold is still being found in the spoil.

At the dam site the mean average flow of the Clutha is 18,000 cusecs. The dam is to be of the mass concrete gravity type, of about 1,200 ft. in crest length, including the spillway section. The spillway section will be built across the diversion channel and will be lined, to form the permanent spillway channel. The discharge over the spillway will be controlled by three gates, each approximately 50 ft. high and 42 ft. wide. The power house will be about 500 ft. long and will house eight 40,000 kW generators. Four of these machines will be installed initially. To supply power for construction work, two minor local hydro schemes plus diesel generators have to be relied upon. The demand for compressed air alone is at the rate of 6,000 cu. ft. per min. Most of the equipment and material required comes from Britain.

The foundations for the dam are being laid in a type of quartz rock which, from tests, should be most stable. At the same time, excavation has not been unduly difficult. When the dam is completed the expectation is that the level of the river behind it will be raised 150 ft. The lake so formed will extend backwards for about 18 miles, without submerging much land that is agriculturally useful. The planning engineers visualise measures later for controlling the level of one or more of the three lakes feeding into the Clutha.

The model settlement for those engaged on the project, and their wives and families, has the most up-to-date amenities, including a school of about twelve classrooms, three or four churches, a shopping centre, post office, library, dance hall, swimming bath and the most recent addition to New Zealand community facilities—a branch of the Totalisator Agency Board. The district also has good trout-fishing and game-shooting.

Aluminium Sheathing for 300 kV Cable for Kitimat

The accompanying illustrations show the extrusion and coiling of a large aluminium tube that will be used to sheathe a power-transmission cable in Canada. Of 4¼ in. outside diameter, with wall thickness of 0·17 in., this is the largest aluminium cable sheathing

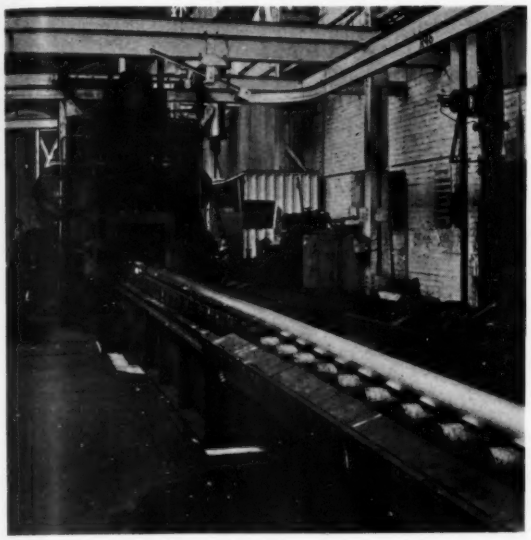

Fig. 1. Aluminium cable sheathing being extruded

tube yet produced, and it is supplied in 400 ft. lengths, unprecedented for a tube of this size. It is being manufactured by Northern Aluminium Co. Ltd., who have already produced many thousands of feet of sheathing tube of ⅜ in. diameter and upwards. As it emerges from the 8,000 ton Fielding & Platt press, each length of the 4¼ in. tube is coiled on to a drum 12 ft. in diameter and 6 ft. wide, with a barrel of 10 ft. diameter. A drum of this size is necessary to allow the tube to be coiled without damage and also to be successfully restraightened when it is uncoiled.

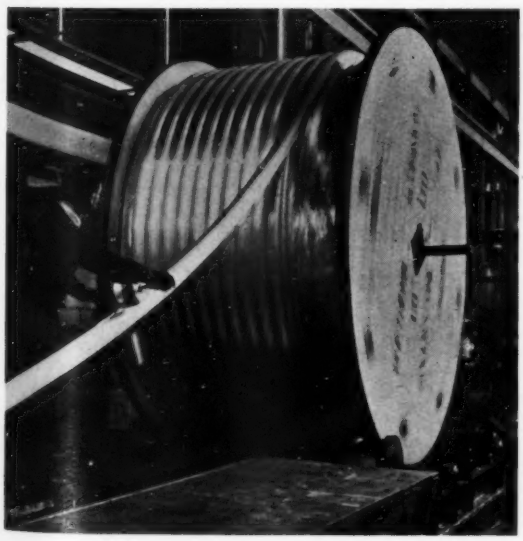

Fig. 2. Coiling the sheathing

Twenty lengths of the tubing have been ordered for sheathing a paper-insulated hollow segmental aluminium conductor that is to operate at 300,000 V. This cable will carry current from the generators at Kemano, British Columbia, to supply the new smelter that Aluminium Company of Canada Ltd. are now building at Kitimat. The diameter of the conductor to be sheathed is 3½ in. and that of the finished cable, after the tube has been shrunk on to it, is about 3·85 in.

The press that produces the tube is the biggest in the country, perhaps the biggest actually in operation in the world, though several of still greater rating are now planned in the United States. The large size of the billet container (20 in. dia.) made possible the production of the 400 ft. lengths of sheathing, the billets each weighing some 1,450 lb.

New Fluid Seal

Hall & Hall Limited, of Hampton, Middlesex, have devised a fluid seal which is claimed to overcome some of the disadvantages of the normal design of U-type packing ring, e.g. wear at the heel caused by pressure distortion. The "Hallprene" seal, as it is called, consists of an impregnated fabric in the form of a U ring between the arms of which a soft, resilient synthetic rubber is inserted. The composition of the

Fig. 1. Sectional "Hallprene" seal

rubber is claimed to be impervious to the action of hydraulic fluids up to a temperature of 250°F. and it is equally suitable for air seals up to this temperature.

In operation, the soft insert is deformed by the fluid pressure and expands the impregnated side walls against the gland housing. The seal is moulded with slightly divergent walls and because the filling is resilient, the walls of the packing ring do not tend to collapse, thus ensuring a perfect seal even though the pressure falls to zero. As the resilient filling is bonded to the fabric ring (which is impregnated with the same synthetic rubber composition) any separation at the joint is scarcely possible, and the rounded surface of the insert ensures that the fluid pressure can readily reach all parts of the exposed surface. It is stated that the seal has been found particularly effective on shafts which are slightly out of alignment or in hydraulic cylinders which have worn oval.

Abstracts from the World Technical Press

Compaction Measurement of Brushwood Pads

A contrivance is described, by means of which the compaction of shrubwood foundation pads in rockfill dams or similar hydraulic structures can be measured; the knowledge of the compaction occurring under a load of dumped rock plays a very important part when calculating the volume of rockfill required in such structures.

Fig. 1 shows the measuring arrangement used in connection with the building of a rockfill dam on the Jade river, north of Wilhelmshafen. It consists of two square sets of boards 100 × 100 cm., 10 cm. thick, between which the shrubwood pad is built up. A 1·5 in. gas pipe 2·5 m. in length is fixed on the bottom square, and passes through another gas pipe 1·3 m. long, 2·5 in. diam., fixed on the upper face of the top square. Both pipes are fitted each at their upper end with screw sockets for additional pipes, so as to extend beyond the rockfill already in place and the water level. The shrubwood pad was 1 m. thick, reduced to 0·90 m. between the two squares. As the load of the rockfill increases, the outer gas pipe sinks with the top square so that the compaction of the pad can easily be measured on the inner pipe.

Referring to the measuring arrangement as illustrated in Fig. 1, the first measurements taken on 16.2.1939 proved that, under a load of 1·5 and 1·6 metric tons per sq. m., the pad had subsided 36 cm., i.e. 40 per cent.; on 25.2.39, when the load varied between 3·2 and 3·3 tons per sq. m., the thickness of the pad had decreased to 39·5 cm., whereupon work on the dam was suspended for a fairly long period. When the last measurement was taken, on 28.10.1940, the pad had been reduced to 28·5 cm. in thickness, corresponding to a subsidence of 61·5 cm., or 68 per cent. This is the first time that the results of such measurements have been published, and it may be assumed that the compaction of shrubwood pads varies more or less in accordance with the construction and original thickness of the pad, the nature of the shrubwood used, as well as with local conditions. (Dr. Karl Lüders, *Die Wasserwirtschaft*, Vol. 43, No. 3, Dec. 1952, p. 74, 2 pp., 3 ff.)

Inaugurations

On June 4, 1952, the Calancasca Power Station, Switzerland, in operation since late summer 1951. (G. A. Tondüry, *Wasser- & Energiewirtschaft*, Vol. 44, August 1952, p. 156, 2 pp., 1 f.)

On June 24, 1952, the Lavey Power Station, on the Swiss stretch of the Rhone. (P.M., *Wasser- & Energiewirtschaft*, same issue as above, p. 158, 2 pp., 1 f.)

On October 4, 1952, the Gondo Power Station, first stage of the Simplon Development. (G. A. Tondüry, *Wasser- & Energiewirtschaft*, Vol. 44, No. 10/11, Oct. Nov. 1952, p. 207.)

On December 10, 1952, Davis Dam, on the Colorado River, the only Bureau of Reclamation dam that had not yet been officially inaugurated. (*Engineering News-Record*, Vol. 149, No. 24, Dec. 1952, p. 28, 1 f.)

Welding H.T. Busbars to Aluminium Conductors

In a paper read by René Rols at a meeting of Section 3 of the Société Française des Electriciens, the author advocates the substitution of welded joints for mechanical joints between flat-bar aluminium conductors on the one hand, and flat-bar conductors or groups of aluminium strips on the other. Problems of this kind, frequently encountered in electro-chemistry and electro-metallurgy, can easily be solved by autogenous welding, using the oxy-acetylene blow-pipe for medium-thick bars, and the casting ladle for very thick bars. In the latter case, it is advisable to have the work performed by specialised aluminium workers. The author concludes that, in H.T. busbars, welded joints are to be preferred to fastening by bolts,

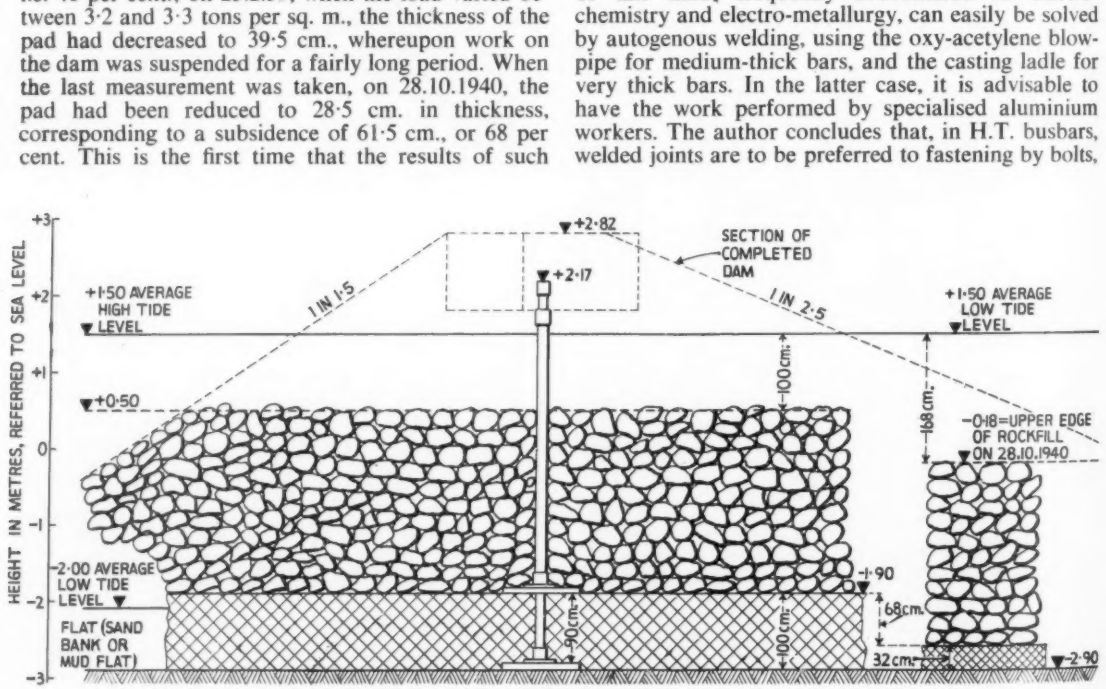

Fig. 1. Compaction measuring equipment for rockfill dam

both from the technical and economic aspects. (René Rols, *Bulletin de la Société Française des Electriciens*, Serie F, Vol. III, No. 25, January 1953, p. 39, 7 pp., 12 ff.)

Rockfill Dams

Recent developments in design and construction of rockfill dams are reviewed with reference to Cesar Cliff Dam in N. Carolina, Kenney Dam in British Columbia, and Bear River Dam in California, the two first dams having a sloping impervious rolled-clay core, while the third has a concrete slab face.

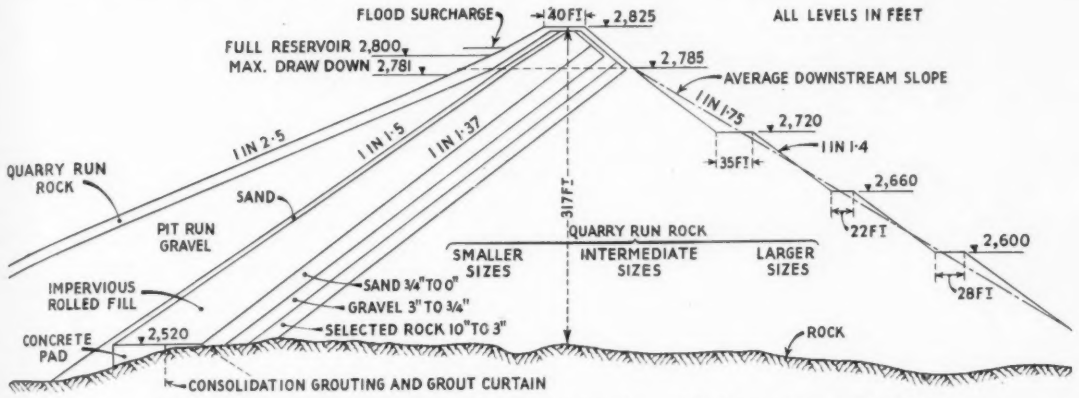

Fig. 1. Kenney Dam, an example of construction with impervious rolled fill

The difference between the two types appears from the appended diagrams.

Most spectacular structure of the former type is Kenney Dam (Fig. 1), 317 ft. in height, which will require close to 4 M cu. yd. of material; design innovations include a concrete pad under the impervious rolled fill, and gunited foundation slopes.

The techniques developed for building concrete-faced rockfill dams are demonstrated to good advantage in Bear River Dam (Fig. 2), 230 ft. high, with 1·4 M cu. yd. of fill, including a similar but smaller dam that plugs an adjacent canyon. Large rock pieces are carefully crane-placed in a layer along the upstream face, and form a relatively solid mortarless masonry. The facing concrete slab, 1 ft. thick at top, 2 ft. 5 in. at bottom, is placed in sections generally 60 ft. square which are separated by expansion joints consisting of folded copper strips and mastic; this technique permits a certain amount of flexibility in the dam surface to accommodate settlement. The expansion joints are backed up by unreinforced concrete beams 4 ft. wide by 2 ft. deep, poured in trenches in the dumped rock.

The bulk of the rock on both types of dam is placed by random dumping in high lifts, allowing the big stone to topple and slide down the slope. Sluicing is done as the rock is dumped.

Shaking-table tests carried out on a model 1/150 the size of the prototype demonstrated the inherent resistance of rockfill dams to earthquake motion, thus confirming general expert opinion that these dams are the safest type of structure in so far as earthquake resistance is concerned. (L. L. Wise, *Engineering News-Record*, Vol. 150, No. 4, Jan. 22, 1953, p. 35, 4 pp., 5 ff.)

The Châtelot Power Station

A full description is given of this Franco-Swiss development which is expected to be put into operation this spring. The civil engineering works have been reviewed in our issue of February 1952, p. 77.

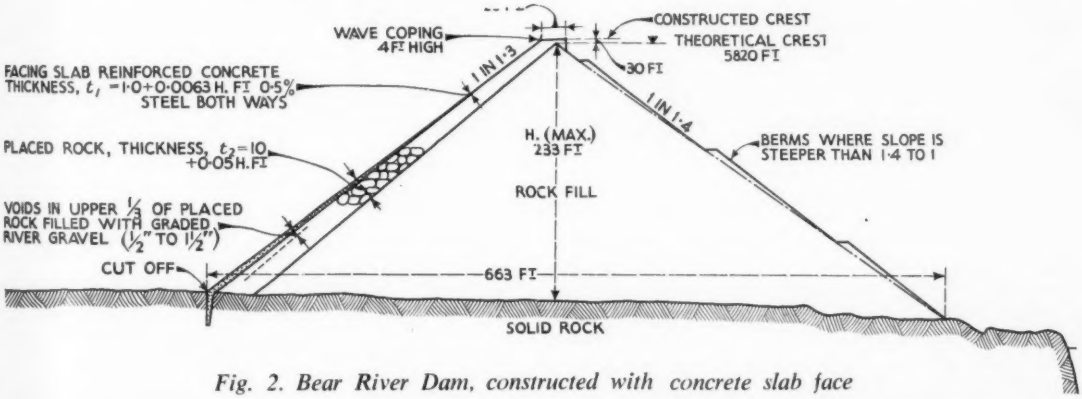
WAVE COPING 4FT HIGH
CONSTRUCTED CREST
THEORETICAL CREST 5820 FT
30 FT
1 IN 1·3
1 IN 1·4
FACING SLAB REINFORCED CONCRETE THICKNESS, t_1 = 1·0+0·0063 H. FT 0·5% STEEL BOTH WAYS
PLACED ROCK, THICKNESS, t_2 = 10 +0·05 H. FT
H. (MAX.) 233 FT
BERMS WHERE SLOPE IS STEEPER THAN 1·4 TO 1
ROCK FILL
VOIDS IN UPPER 1/3 OF PLACED ROCK FILLED WITH GRADED RIVER GRAVEL (1/2" TO 1 1/2")
CUT OFF
663 FT
SOLID ROCK

Fig. 2. Bear River Dam, constructed with concrete slab face

The main characteristics of the electrical layout are dictated by the fact that the station is to deliver a half of its production to France at 150 kV, and the other half to Switzerland, partly at 60 kV and partly at 150 kV. There are no less than four switching

stations, one each for the generators themselves, the 60 kV system, the 150 kV system, and the 8 kV system for internal requirements. Control is shared by three fully equipped groups—the main group (with control desks and switchboard for the whole plant), the switchboards for the generating sets, and the ancillary services. To meet the emergency of temporary stoppages during the dry winter periods, when temperature in the district sinks very low, an independent, oil-burning heating system is provided in the power house.

Serving three different transmission systems and two countries, the plant is equipped with an extensive telephone system; in addition to the private network and connections with the public service of the two countries, there are two separate high-frequency exchanges, each with its own transmission lines.

The average production of energy in actual practice is assessed at 100,000 M kWh per annum, of which 57 per cent. is in the winter period. Capital expenditure, calculated on the basis of the prices in force in February 1950, amounts to 37 M Sw. Fr. The production cost of winter energy is estimated at 0·035 Sw. Fr. per kWh. (F. W. Brigger, *Bulletin de l'Association Suisse des Electriciens*, Vol. 43, No. 23, Nov. 15, 1952, p. 921, 12 pp., 16 ff.)

Automatic Regulation of Frequency and Energy Exchanges in Electric Systems

The automatic regulation of frequency and energy exchanges between networks presents a problem of growing importance in view of the increasing capacities of generating installations, and of the extent of the interconnected systems. Adopted long ago by certain networks, automatic regulation is bound to become the rule in the near future, and the techniques applied are unceasingly improved and developed. The considerations of the author given in a paper presented to the Société Francaise des Electriciens, apply more particularly to the case of the French national grid and to European interconnection; the author analyses successively the general organisation and the various methods of regulation, and finally reviews a few special problems inherent in automatic regulation as applied in extensive systems. In the discussion which followed this lecture, M. Gaden, head of the Alsthom-Charmilles research department, and M. Poma, director of the "Société Intercommunale Belge d'Electricité," expressed their agreement with the author's views. (François Cahen, *Bulletin de la Société Française des Electriciens*, Series 7, Vol. III, No. 26, Feb. 1953, p. 59, 14 pp., 13 ff.)

Upper Rhone Development

A description is given of the Ernen installations which constitute the second stage of a development on the upper valley of the Rhone in the Valais canton, the first stage (Ernen-Mörel stretch) having been commissioned 10 years ago. The new Ernen scheme drains a catchment area of 316 sq. km., of which 216 sq. km. is in the Rhone basin proper, and 100 sq. km. in the watershed of the Binna, a left-bank tributary of the Rhone. From the Rhone intake, set up near Gluringen at El. 1,299·8 m., the water is conveyed to the Binneggen surge tank (El. 1,270·3 m.) first through a sand-trap designed for a discharge of 7·5 cu. m. per sec., and then through a 3·2 km. long concrete canal which connects with a gravity tunnel 9 km. in length. The Binna intake is set up on a small reservoir which can store 200,000 cu. m. at a maximum level of 1,308 m., and acts as a daily and weekly compensation pool during the low-water period; the water also flows from this intake to the Binneggen surge tank through a 3·8 km. long tunnel from which a surface penstock conveys it to the Ernen power house, whose tailrace is in direct connection with the supply canal of the Mörel plant. A spillway at the surge tank evacuates waste water through an underground channel to the Binna gorge, while another spillway is set up upstream of the Mörel power house to evacuate excess water from the Mörel supply tunnel to the Rhone. The equipment of the Ernen plant consists of two 16,200 kW Francis turbines driving each a 20,000 kVA alternator. The new plant will produce 57,000 M kWh in winter and 108,000 M kWh in summer, i.e. an average of 165,000 M kWh p.a. (*Bulletin de l'Association Suisse des Electriciens*, Vol. 33, No. 1, January 10, 1953, p. 23, 2 ff.)

CLASSIFIED ADVERTISEMENTS

Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

Appointments Vacant

The engagement of persons answering Situations Vacant advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18—64 inclusive or a woman aged 18—59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

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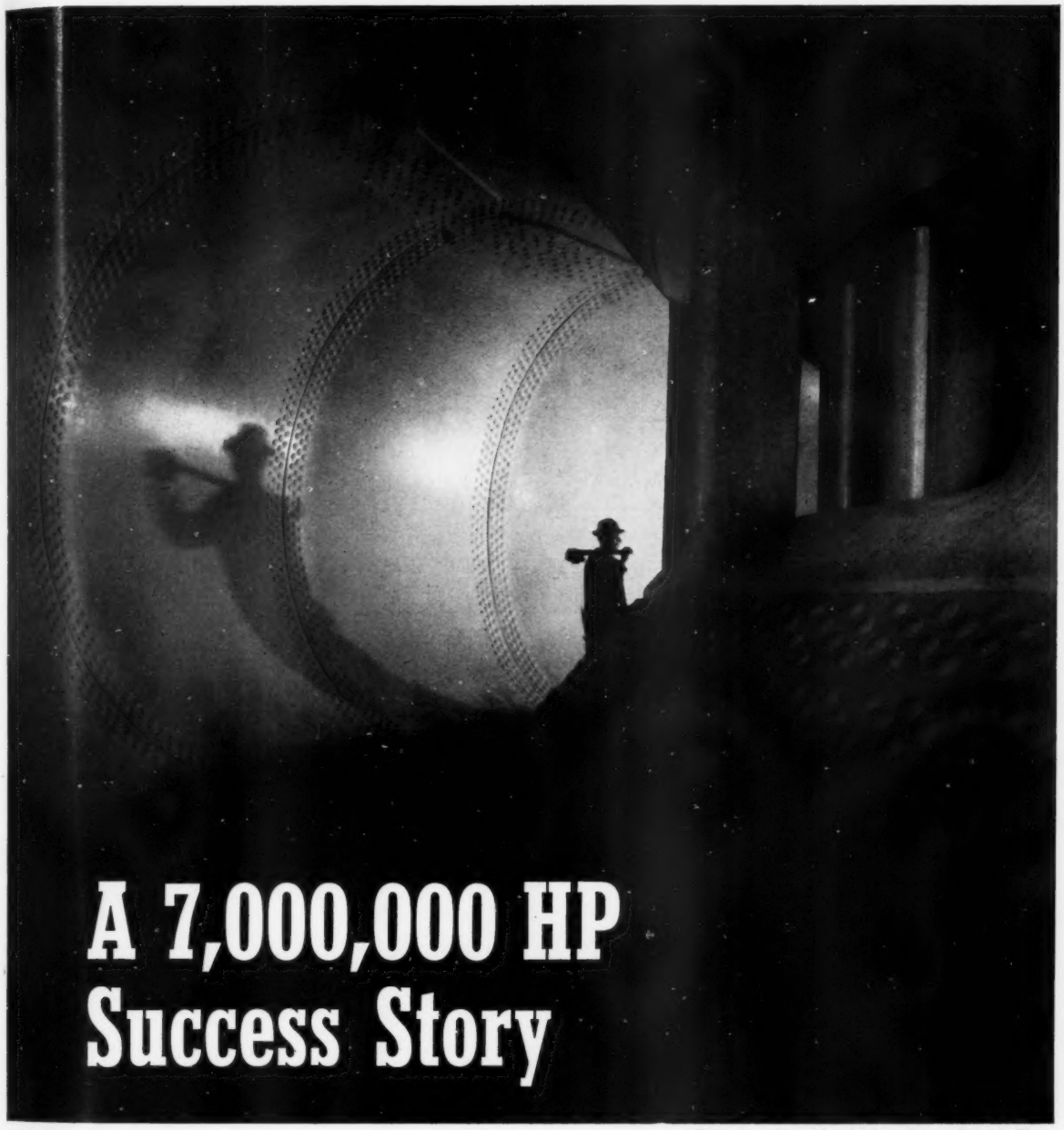

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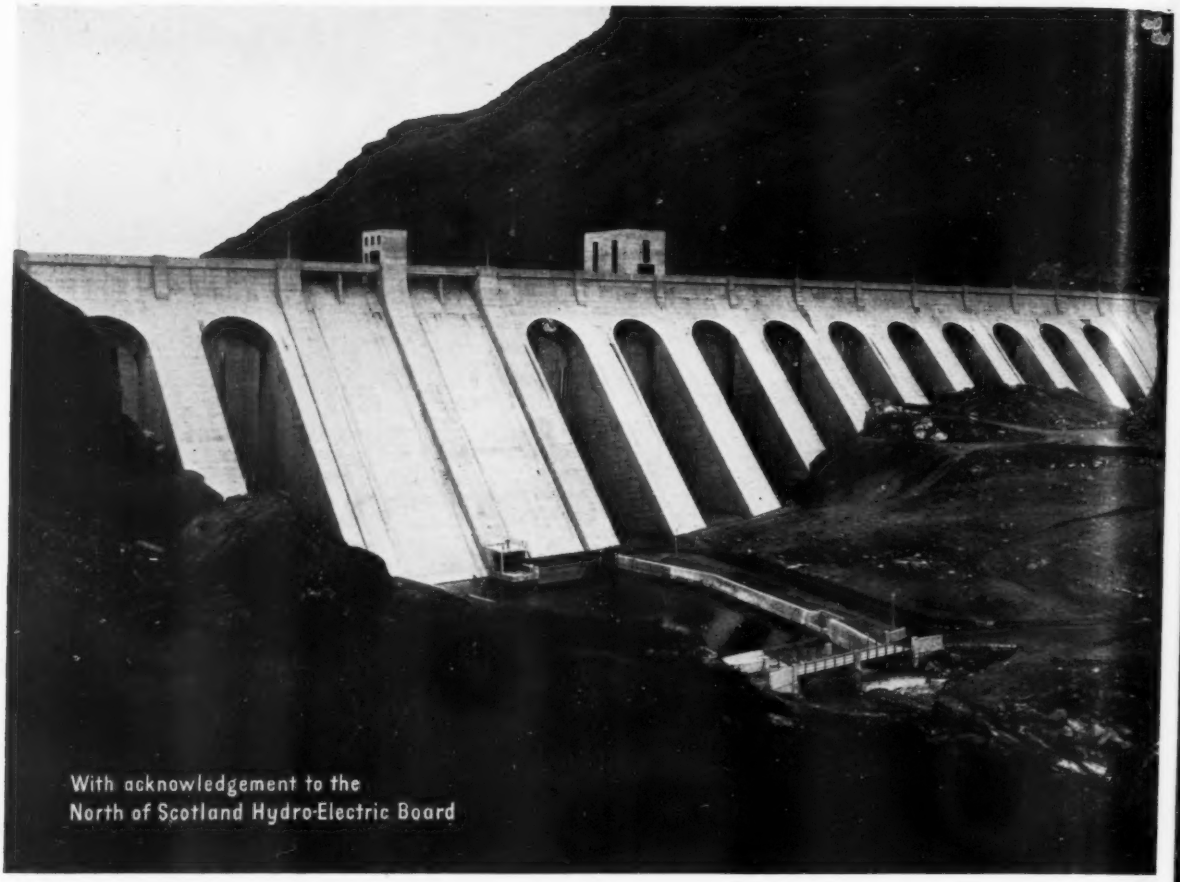

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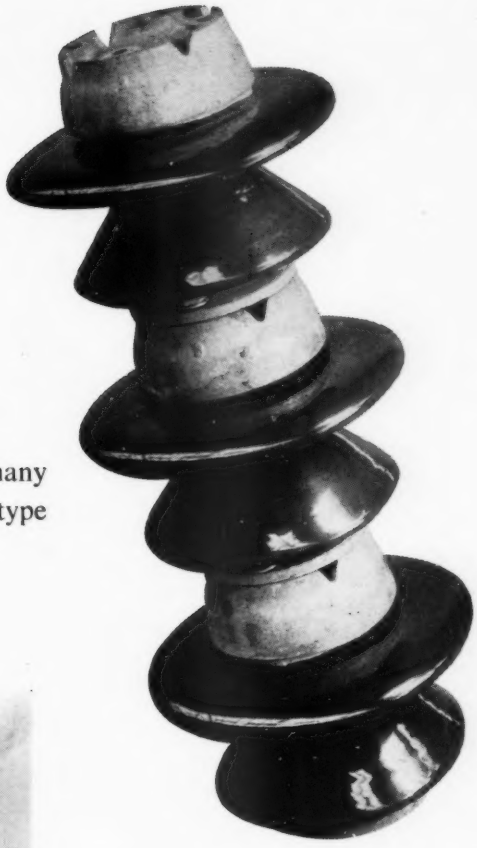
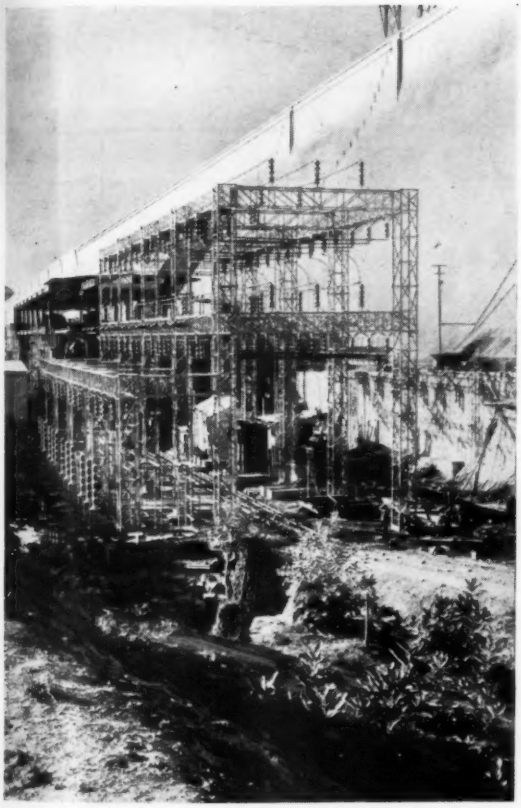


The Mettur Dam sub-station is one of many in South India equipped with posts type P.642 for 66KV and 110KV.



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Exterior view of the power station

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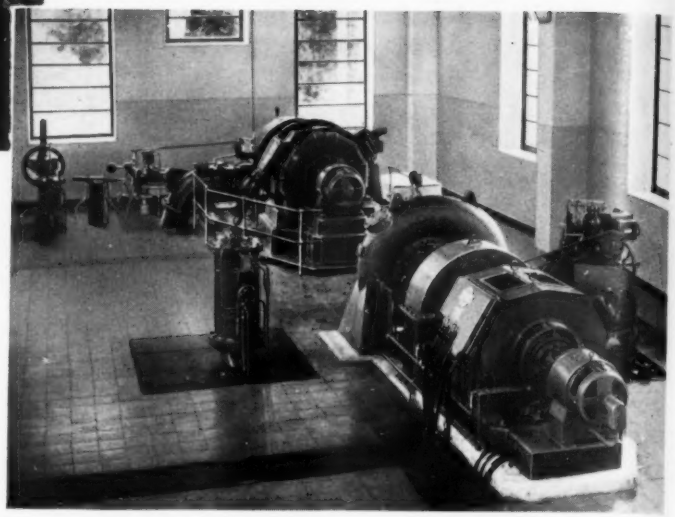

Interior of the power station showing the 250 kW GILKES Turgo Impulse Wheel in the background and the 500 kW GILKES Francis Turbine in the foreground

No less important than their large schemes are the North of Scotland Hydro-Electric Board's smaller installations supplying the more isolated regions of Scotland. The Kerry Falls Station is a good example of one of these, having ultimate capacity of 1250 kW. This will eventually comprise two 500 kW GILKES Francis Turbine Units, and one 250 kW GILKES Turgo Impulse Wheel unit. A single pipeline 4700 feet long and 45 inches diameter supplies the power station, the net head at the turbines being 145 feet. Because of the considerable length of pipeline compared with the relatively low head, both Francis Turbines are fitted with the GILKES "Giljet" governing system, thus avoiding the need for relief valves and a surge tower.

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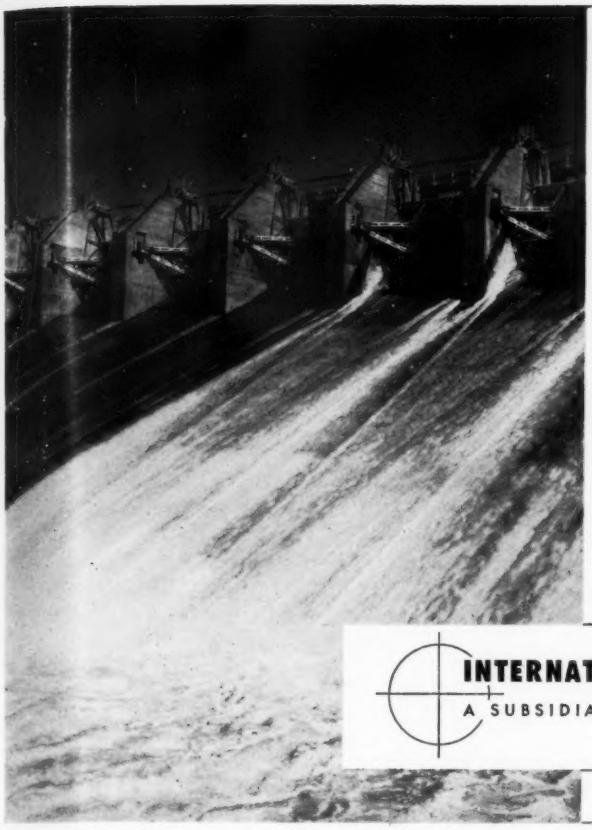

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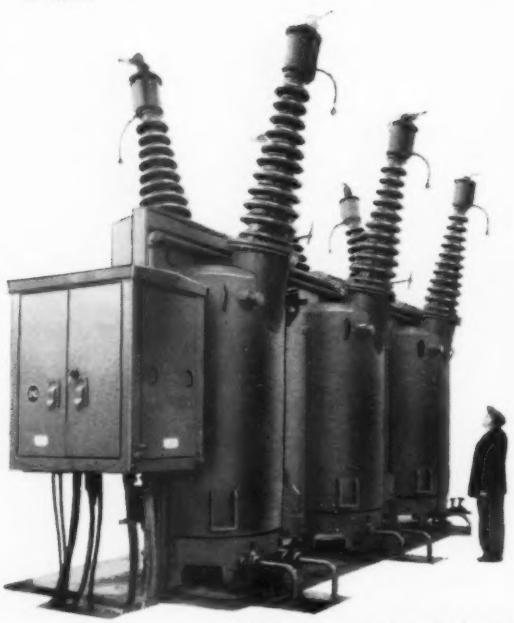

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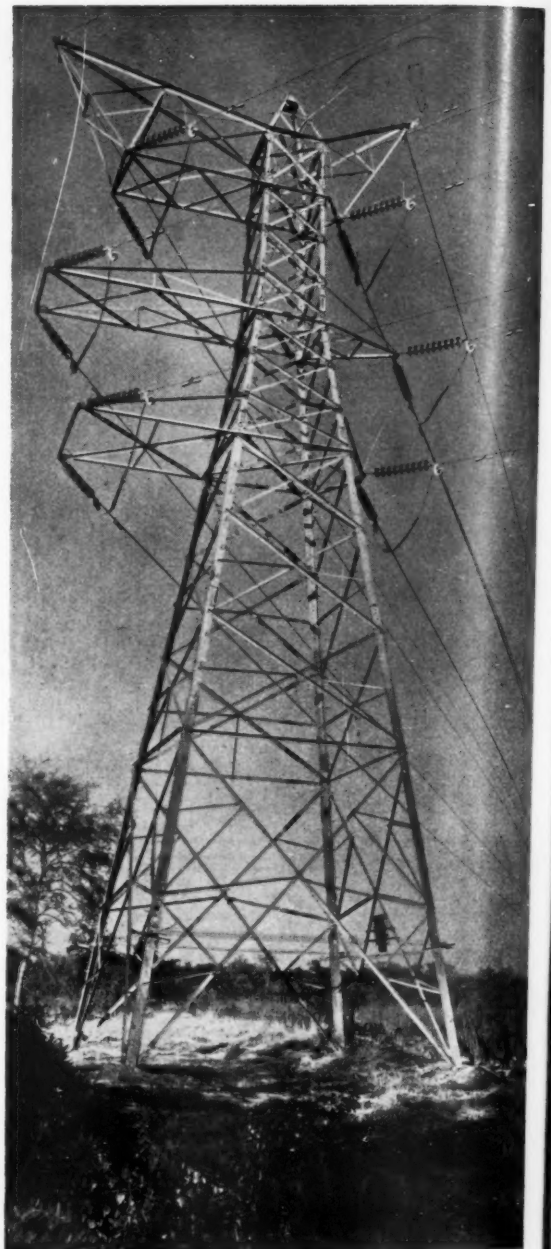

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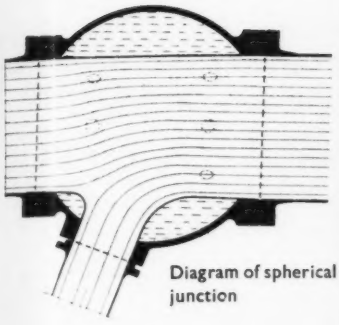

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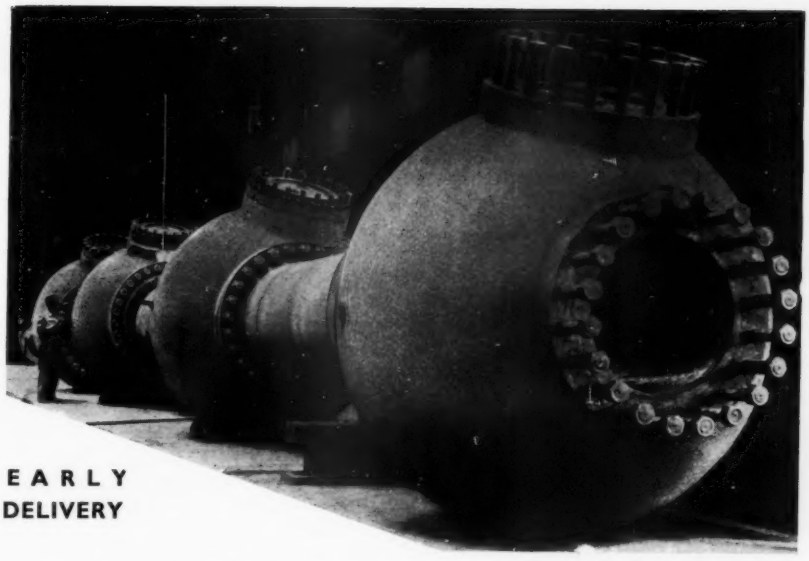

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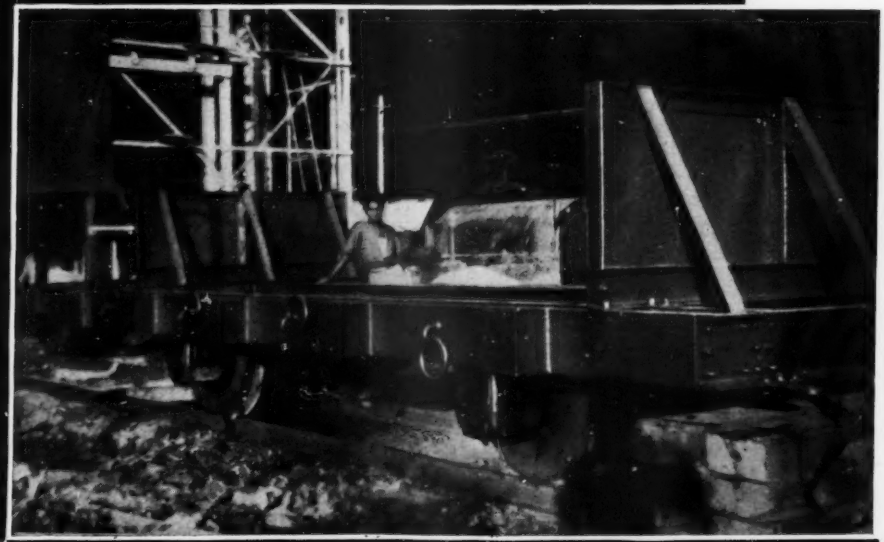

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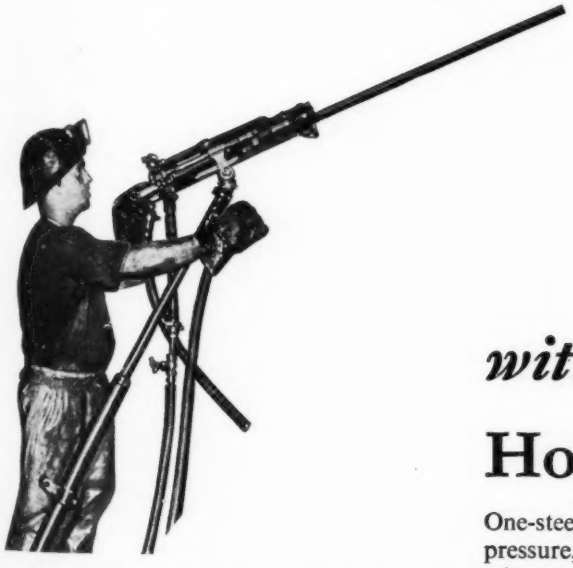

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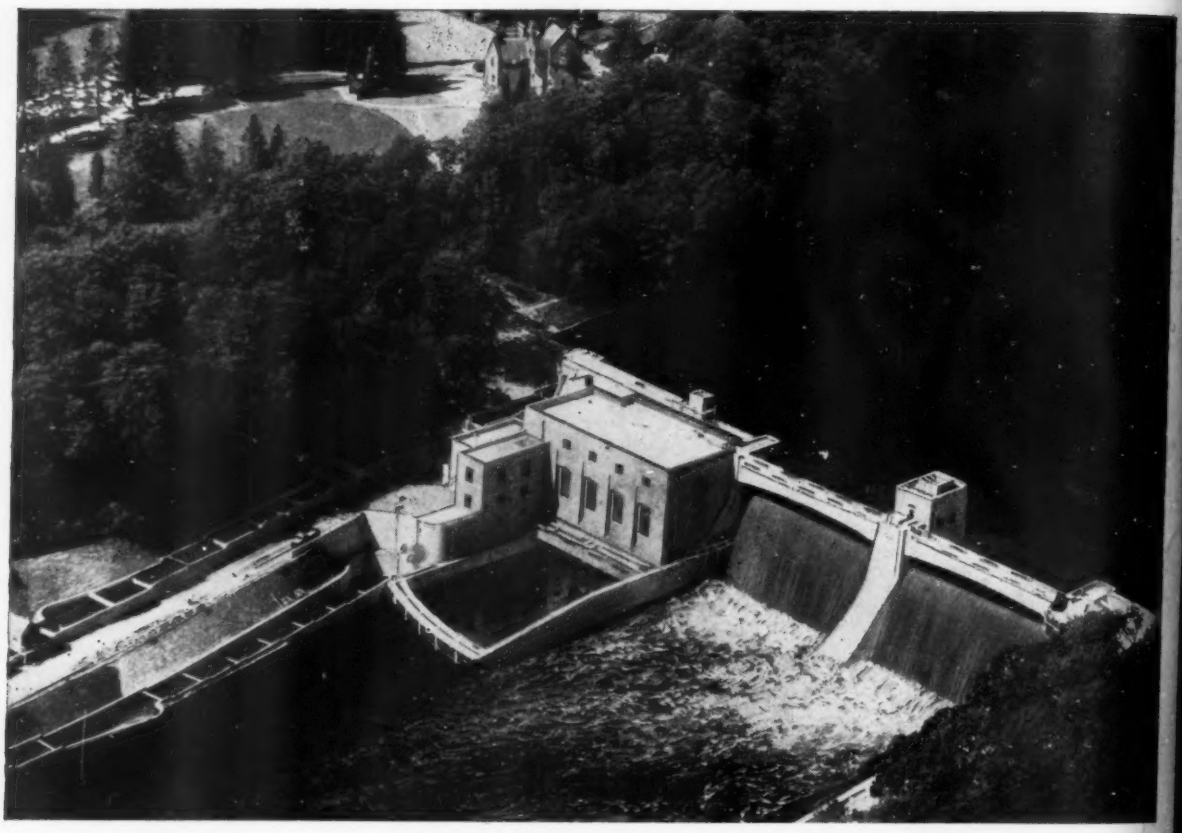

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